ENGINEER MANUAL

EM 1110-3-130
April 1984

ENGINEERING AND DESIGN

Geometrics for Roads, Streets, Walks, and Open Storage Areas

Mobilization Construction

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
OFFICE OF THE CHIEF OF ENGINEERS

DAEN-ECE-G

DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, D.C. 20314

EM 1110-3-130

Engineer Manual
No. 1110-3-130

9 April 1984

Engineering and Design
GEOMETRICS FOR ROADS, STREETS, WALKS, AND OPEN STORAGE AREAS
Mobilization Construction

1. Purpose. This manual provides guidance for design and layout of roads, streets, walks, and open storage areas for U.S. Army mobilization facilities.

2. Applicability. This manual is applicable to all field operating activities having mobilization construction responsibilities.

3. Discussion. Criteria and standards presented herein apply to construction considered crucial to a mobilization effort. These requirements may be altered when necessary to satisfy special conditions on the basis of good engineering practice consistent with the nature of the construction. Design and construction of mobilization facilities must be completed within 180 days from the date notice to proceed is given with the projected life expectancy of five years. Hence, rapid construction of a facility should be reflected in its design. Time-consuming methods and procedures, normally preferred over quicker methods for better quality, should be de-emphasized. Lesser grade materials should be substituted for higher grade materials when the lesser grade materials would provide satisfactory service and when use of higher grade materials would extend construction time. Work items not immediately necessary for the adequate functioning of the facility should be deferred until such time as they can be completed without delaying the mobilization effort.

FOR THE COMMANDER:

PAUL F. KAVANAUGH
Colonel, Corps of Engineers
Chief of Staff

DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314

Engineer Manual
No. 1110-3-130

9 April 1984

Engineering and Design
GEOMETRICS FOR ROADS, STREETS, WALKS, AND OPEN STORAGE AREAS
Mobilization Construction

	Paragraph	Page
APPENDIX A. REFERENCES		A-1

LIST OF FIGURES

CHAPTER 1

GENERAL

1-1. Purpose and scope. This manual establishes the geometric design criteria for roads, streets, walks, and open storage areas. This manual sets forth the approaches and traffic flow criteria for guidance in determining types and configurations best suited for mobilization construction. This manual presents general criteria and is intended for use in conjunction with EM 1110-3-131, EM 1110-3-132, EM 1110-3-136, and EM 1110-3-150.

1-2. Definitions of pertinent terms. The definitions of terms relative to highway design are given in lists of definitions presented in the manuals of AASHTO as a part of specific procedures referenced from this manual, D6.1 and as described below.

a. Access highways. An access highway is an existing or proposed public highway which is needed to provide highway transportation services from an Army reservation to suitable transportation facilities. This will not include installation highways within the boundary of an Army reservation, but may include a highway through an Army reservation that has been dedicated to public use if reasonable assurance can be given that future closure to public use will not be required. The design and construction of access highways are normally the responsibility of the state, county, or local authorities. The design criteria of these authorities will be used for access road construction but with due consideration given to the mobilization effort.

b. Installation highways. Installation highways include all roads and streets within the site limits of Army installations which are constructed and maintained by the Department of Defense. All installation highways are classified in accordance with their relative importance to the installation as a whole and with respect to the composition, volume, and characteristics of the traffic using them. Design criteria for roads and streets within Army installations are presented herein.

1-3. Highway planning. The planning of the general road system is an integral part of installation master planning. Major objectives of master planning are the grouping of related functions reasonably close to each other and the interrelating of land-use areas for maximum efficiency, speed of construction, and economy of operation. The connecting road system should be planned in keeping with these objectives to minimize on-post travel and permit the optimum circulation of traffic originating both outside and within the installation. Traffic studies may not be available during a mobilization situation, so good engineering judgment and assessment of current and/or near future needs must be made to determine traffic requirements. The geometric design of highway facilities should provide for safe, smooth, and convenient traffic movement consistent with time limitations, topographical conditions, and to the extent possible, economical construction. Existing roads and streets at Army installations can be classified in accordance with requirements presented in tables 1-1 and 1-2. The elements to be given primary consideration in such classifications are pavement width, shoulder width, degree and length of slopes (grade), and passing sight distance. Values for these elements should be essentially equal to or greater than the minimum requirements for classification assigned. All of the requirements in table 1-1 or 1-2 should be considered, but requirements other than those just listed can be given greater latitude.

1-4. Traffic. The volume and composition of the traffic determines the geometric requirements for roads, streets, walks, and open storage areas. Type, volume, character, frequency, and composition of traffic at Army installations are related to size, type, and mission of the installation. The size, type, and mission of the installation provide information as to its functional requirements, indicating character and size of vehicles. Types of vehicles, types of terrain, and frequency of use establish the traffic classification in which roads and streets fall. The system of highway classification outlined and defined above is believed sufficiently broad for the classification of all roads and streets within an Army installation regardless of type and mission. Classification reflecting character of traffic is based upon the characteristics and dimensions of existing civilian and Army vehicles. Army vehicles include not only wheeled vehicles but also combined wheel and tracked vehicles. It is essential that the designer be aware of the vehicular traffic anticipated prior to selection of the type design to use on a particular project.

Table 1-1. Geometric Criteria for Classified Roads Within "Open" Areas of Army Installations (Rural Areas)

Design Controls and Elements	Class B Road[a] Two-Lane Road Flat	Class B Road[a] Two-Lane Road Rolling	Class B Road[a] Two-Lane Road Mountainous	Class D Road[a] Two-Lane Road Flat	Class D Road[a] Two-Lane Road Rolling	Class D Road[a] Two-Lane Road Mountainous	Class E Road[a] Two-Lane Road[b] Flat	Class E Road[a] Two-Lane Road[b] Rolling	Class E Road[a] Two-Lane Road[b] Mountainous
Design Controls:									
Traffic composition:[1]									
T = 0%									
ADT	4,000-6,000	4,000-6,000	4,000-6,000	1,000-4,000	1,000-4,000	1,000-4,000	Under 1,000	Under 1,000	Under 1,0
DHV[2]	600-900	600-900	600-900	150-600	150-600	150-600	Under 150	Under 150	Under 150
T = 10%									
ADT	3,600-5,500	3,000-4,600	2,400-3,500	950-3,600	770-3,000	600-2,400	Under 950	Under 770	Under 600
DHV[3]	550-820	450-690	360-530	140-550	115-450	90-360	Under 140	Under 115	Under 90
T = 20%									
ADT	3,300-5,000	2,500-3,700	1,600-2,500	870-3,300	630-2,500	400-1,600	Under 870	Under 630	Under 400
DHV[3]	500-750	380-560	240-380	130-500	95-380	60-240	Under 130	Under 95	Under 60
T = 30%									
ADT	3,000-4,700	2,000-3,200	1,200-2,100	770-3,000	570-2,100	330-1,200	Under 770	Under 570	Under 330
DHV[3]	450-700	310-480	180-310	115-450	85-310	50-180	Under 115	Under 85	Under 50
Design speed, mph	70	60	50	55	45	35	55	45	35
Average running speed, mph	49	45	40	43	37	30	43	37	30
Cross-Section Elements:									
Pavements:									
Minimum width of traffic lanes, ft[4]									
With barrier curbs	12	12	12	10	10	10	10	10	10
Without barrier curbs	12	12	12	10	10	10	10	10	10
Minimum distance between barrier curbs, ft[5]	29	29	29	24	24	24	20	20	20
Desirable lateral clearance, to obstructions, ft	6	6	6	4	4	4	2	2	2
Normal cross slope, in./ft		1/8 to 1/4			3/16 to 3/8			1/4 to 1/2	
Curbs:[6]									
Types			See paragraph 3-2.b						

Table 1-1. Geometric Criteria for Classified Roads Within "Open" Areas of Army Installations (Rural Areas) (Continued)

Design Controls and Elements	Class B Road[a] Two-Lane Road			Class D Road[a] Two-Lane Road			Class E Road[a] Two-Lane Road[b]		
	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous	Flat	Rolling	Mountainous
Offset for barrier curbs	2.5	2.5	2.5	2.0	2.0	2.0	0	0	0
Medians[7]	See figure 3-1								
Shoulders:[8]									
Minimum width, shoulders on roads without barrier curbs, ft	10	8	8	8	6	4	6	6	4
Normal cross slope, in./ft	3/8 to 1/2			1/2 to 3/4			3/4 to 1		
Type	Dustless and stable for all-weather use			Stabilized with select material			Compacted soil		
Guardrails, guideposts, and earth slopes	See figure 3-2								
Bridge clearance	See paragraph 3-3e								
Design Elements:									
Sight distance:									
Minimum stopping sight distance, ft	600	475	350	415	310	240	415	310	240
Minimum passing sight distance, ft	2,300	2,000	1,700	1,850	1,500	1,050	1,850	1,500	1,050
Horizontal alinement:									
Horizontal curves, maximum curvature									
Desirable maximum	1°30'	2°00'	3°00'	2°30'	3°30'	6°00'	2°30'	3°30'	6°00'
Absolute maximum[9]									
Where snow and ice are not factors	4°00'	5°30'	8°00'	7°00'	10°30'	18°00'	7°00'	10°30'	18°00'
Where snow and ice are factors	3°00'	4°30'	7°00'	5°45'	9°00'	16°30'	5°45'	9°00'	16°30'
Pavement widening	See table 3-1 and figure 3-3								

Table 1-1. Geometric Criteria for Classified Roads Within "Open" Areas of Army Installations (Rural Areas) (Continued)

Design Controls and Elements	Class B Road[a] Two-Lane Road Flat	Rolling	Mountainous	Class D Road[a] Two-Lane Road Flat	Rolling	Mountainous	Class E Road[a] Two-Lane Road[b] Flat	Rolling	Mountainous
Vertical alinement:									
Grade:[10]									
Desirable maximum									
Percent	3	3	4	4	5	6	5	6	7
Critical length, ft[11]	1035	1035	720	720	550	450	550	450	375
Absolute maximum for permanent installations									
Percent	5	6	6	7	8	9	8	9	10
Critical length, ft[11]	1000	660	450	850	550	275	900	600	400
Absolute maximum for temporary installations									
Percent	6	7	8	8	9	10	10	11	12
Critical length, ft[11]	825	550	325	750	500	250	700	525	375
Minimum, percent		0.3				0.5			
Vertical curves[12]									
K for determining safe length									
Crest vertical curves	240	150	80	115	65	40	115	64	40
Sag vertical curves	140	100	70	85	60	45	85	60	45
Minimum length, ft	210	180	150	165	135	105	165	135	105

NOTES:
1 The symbol "T," with percentage limitations, represents the proportion of total traffic composed of buses, trucks, and track-laying vehicles; the remainder are light delivery trucks and passenger cars.
2 The DHV is equal to approximately 15 percent of the ADT.
3 These values show the mixed traffic volume which requires the same operational area as that required by traffic composed of light-delivery trucks and passenger cars. These DHV's are based on the indicated percentage of the daily volume and may be overconservative in some instances because the percentages of trucks, track-laying vehicles, etc., during peak hours are generally considerably lower than the average percentage during all hours.
4 The traffic lane widths indicated are for use on roads where the traffic will consist principally of vehicles with maximum overall widths of 8 ft. or less. For determining traffic lane width for excessive-width vehicles, see paragraph 3-1.b.
5 Distance shown is the minimum distance between face of curbs where Class B roads require more than 2-lanes, additional lane widths are to be added to minimum distance between curbs.
6 Generally, curbs will not be provided on roads in open areas. See paragraph 3-2 for exceptions on provision of curbs within open areas at Army installations. The curb offset is measured from the edge of the pavement to the vertical face of the curb on the curb portion of a combined curb and gutter.
7 Where traffic volume requires construction of multilane roads, opposing traffic should be separated by medians. Width and location of medians, median shoulders, and median curbs are discussed in paragraph 3-3.b.
8 There should be a color or textural contrast between pavement and shoulder surface sufficient to clearly define the pavement and shoulders in all types of weather.

Table 1-1. Geometric Criteria for Classified Roads Within "Open" Areas of Army Installations (Rural Areas) (Continued)

NOTES: (Continued)

9 Absolute maximum values shown were calculated on the basis of a maximum rate of superelevation of 0.10. Absolute value for horizontal curves will have to be recalculated if a maximum rate of superelevation other than 0.10 is used.

10 See paragraph 3-6.a. for exception to this criteria.

11 The term "critical length" is used to indicate the maximum length of a designated upgrade upon which a loaded truck can operate without an unreasonable reduction in speed. Methods for determination of critical length are discussed in paragraph 3-6.a.(1).

12 The minimum lengths of vertical curves are determined by multiplying "K" times the algebraic difference of grades (in percent).

a The DHV is in total vehicles per hour for all lanes in both directions.

b For single lane roads use criteria of Class E mountainous.

Table 1-2. Geometric Criteria for Classified Street Within "Built-up" Areas of Army Installations

Design Controls and Elements	Class B Street[a] Two-Lane Street Flat	Class B Street[a] Two-Lane Street Rolling	Class D Street[a] Two-Lane Street Flat	Class D Street[a] Two-Lane Street Rolling	Class E Street[a] Two-Lane Street Flat	Class E Street[a] Two-Lane Street Rolling
Design Controls						
Traffic composition[1]						
T = 0%						
ADT	7,500-10,000	7,500-10,000	2,100-7,500	2,100-7,500	Under 2,100	Under 2,100
DHV[2]	900-1,200	900-1,200	250-900	250-900	Under 250	Under 250
T = 10%						
ADT[3]	6,800-9,100	5,700-7,700	1,900-6,800	1,600-5,700	Under 1,900	Under 1,600
DHV[3]	810-1,090	680-920	230-810	190-680	Under 230	Under 190
T = 20%						
ADT[3]	6,200-8,300	4,600-6,300	1,800-6,200	1,300-4,600	Under 1,800	Under 1,300
DHV[3]	750-1,000	550-760	220-750	160-550	Under 220	Under 160
T = 30%						
ADT[3]	5,800-7,700	4,200-5,300	1,600-5,800	1,100-4,200	Under 1,600	Under 1,100
DHV[3]	700-920	500-640	190-700	130-500	Under 190	Under 130
Design speed, mph	50	40	40	30	40	30
Average running speed, mph	36	32	32	25	32	25
Cross-Section Elements:						
Pavements:						
Minimum width of lanes, ft[4]						
With barrier curbs						
Traffic	12	12	11	11	10	10
Parking[5]	None	None	8	8	8	8
Without barrier curbs						
Traffic	12	12	11	11	10	10
Minimum distance between barrier curbs, ft[4, 6]						
With parking lanes[5]	None	None	41	41	36	36
Without parking lanes[7]	29	29	25	25	20	20
Desirable lateral clearance to obstructions, ft	6	6	4	4	2	2
Normal cross slope, in./ft	1/8 to 1/4		3/16 to 3/8			

Table 1-2. Geometric Criteria for Classified Streets Within "Built-up" Areas of Army Installations (Continued)

Design Controls and Elements	Class B Street[a] Two-Lane Street Flat	Class B Street[a] Two-Lane Street Rolling	Class D Street[a] Two-Lane Street Flat	Class D Street[a] Two-Lane Street Rolling	Class F Street[a] Two-Lane Street Flat	Class F Street[a] Two-Lane Street Rolling
Curbs:[8]						
Types	See paragraph 3-2.b.					
Offset for barrier curbs, ft	2.5	2.5	1.5	1.5	1.5	1.5
Medians[9]	See figure 3-1					
Shoulders:[10]						
Minimum width, shoulders on streets without barrier curbs, ft	10	8	8	8	8	6
Normal cross slope, in./ft	3/8 to 1/2		1/2 to 3/4			
Type	Dustless and stable for all weather use					
Guardrails, guideposts, and earth slopes	See figure 3-2					
Bridge clearance	See paragraph 3-3e					
Design Elements						
Sight distance:						
Minimum stopping sight distance, ft	350	275	275	200	275	200
Horizontal alinement:						
Horizontal curves						
Absolute maximum for normal crown section	0°30'	0°45'	0°45'	1°30'	0°45'	1°30'
Absolute maximum for superelevated section[11]	5°30'	9°15'	9°15'	17°15'	9°15'	17°15'
Pavement widening	See table 3-1 and figure 3-3					
Vertical alinement:						
Grade						
Desirable maximum						
Percent	3	3	4	4	5	6
Critical length, ft[12]	900	550	750	475	400	200

Table 1-2. Geometric Criteria for Classified Streets Within "Built-up" Areas of Army Installations
(Continued)

Design Controls and Elements	Class B Street[a] Two-Lane Street Flat	Rolling	Class D Street[a] Two-Lane Street Flat	Rolling	Class E Street[a] Two-Lane Street Flat	Rolling
Absolute maximum for permanent installations						
Percent	4	5	6	7	7	8
Critical length, ft[12]	675	200	500	200	450	175
Absolute maximum for temporary installations						
Percent	6	6	7	8	8	9
Critical length, ft[12]	500	275	450	200	200	150
Minimum, percent		0.3			0.5	
Vertical curves[13]						
K for determining safe length						
Crest vertical curves	80	50	50	28	50	28
Sag vertical curves	70	50	50	35	50	35
Minimum length, ft.	150	120	120	90	120	90

NOTES:

1 The symbol "T," with percentage limitations, represents the proportion of total traffic composed of buses, trucks, and track-laying vehicles; the remainder are light-delivery trucks and passenger cars.

2 The DHV is equal to approximately 12 percent of the ADT.

3 These values show the mixed traffic volume which requires the same operational area as that required by traffic composed of light-delivery trucks and passenger cars. These DHV's are based on the indicated percentage of the daily volume and may be overconservative in some instances because the percentages of trucks, track-laying vehicles, etc., during peak hours are generally considerably lower than the average percentage during all hours.

4 The traffic and parking lane widths indicated are for use on streets where the traffic will consist principally of vehicles with maximum overall widths of 8 ft or less. For determining traffic lane width for use of excessive-width vehicles, see paragraph 3-1.b. Traffic lanes of streets without curbs in warehouse areas should not be less than 12 ft regardless of class. The total width of streets with curbs adjacent to warehouses should not be less than 30 ft between curbs regardless of class. The values given for width of parking lanes is the distance between the outside edge of the adjacent traffic lane and the face of the curb for Type IV curbs. The width of gutter in combined curb and gutter (Types I and III curbs) may be included in the width of parking lane provided the gutter is as strong structurally as the adjoining pavement, otherwise the width of parking lane shown will be the distance between the outside edge of the adjacent traffic lane and the inside edge of the gutter.

5 See paragraph 3-2 for criteria relative to provision of parking facilities.

6 Distance shown is the minimum distance between face of curbs.

7 Where Class E streets are designed with barrier curbs, curb offsets are not required adjacent to traffic lanes.

8 Generally, barrier curbs will be provided on streets in built-up areas. See paragraph 3-2 for exceptions on provision of curbs within built-up areas at Army installations. Types I and IV curbs greater than 6 in. in height and Type III curbs greater than 18 in. in height are considered to be lateral obstructions. The curb offset is measured from the edge of the pavement to the vertical face of the curb or the curb portion of a combined curb and gutter.

9 Where traffic volume requires construction of multilane streets, opposing traffic should be separated by medians. Width and location of medians, median shoulders, and median curbs are discussed in paragraph 3-3.b. Generally, medians are provided with barrier curbs in built-up areas.

Table 1-2. Geometric Criteia for Classified Streets Within "Built-up" Areas of Army Installations
(Continued)

NOTES: (Continued)

10 There should be a color or textural contrast between pavement and shoulder surface sufficient to clearly define the pavement and shoulders in all types of weather.

11 Absolute maximum values shown were calculated on the basis of a maximum rate of superelevation of 0.02. Superelevation rate of 0.04 or 0.06 may be used on streets in which case the absolute maximum values for horizontal curves will have to be recalculated.

12 The term "critical length" is used to indicate the maximum length of a designated upgrade upon which a loaded truck can operate without an unreasonable reduction in speed. Methods for determination of critical length are discussed in paragraph 3-6.a.(1).

13 The minimum lengths of vertical curves are determined by multiplying "K" times the algebraic difference of grades (in percent).

14 On-street parking will not be provided on new Class B or C streets. Dimension given is applicable only to existing streets.

a The DHV is given in total vehicles per hour for all lanes in both directions.

U. S. Army Corps of Engineers

CHAPTER 2

DESIGN CONSIDERATIONS

2-1. General. Geometric design deals with the dimensions of the visible features of a facility such as alinement, sight distances, widths, slopes, and grades. Geometric design critieria are set forth in tables 1-1 and 1-2 and discussed in subsequent paragraphs.

2-2. Road and street types.

a. Designations of types. Highways are generally typed according to the number of traffic lanes as single-, two-, and three-lane, and undivided or divided multilane (four or more traffic lanes) highways. When information is available relative to volume and composition of traffic and type of terrain for a proposed highway, the type required can be readily determined by comparing the traffic volume expected on the proposed road or street with the design hourly volume shown in tables 1-1 and 1-2.

b. Single-lane roads. Geometric design criteria for single-lane roads are shown in table 1-1 under "Class E Roads - mountainous." Where shoulders are not sufficiently stable to permit all-weather use and the distance between intersections is greater than 1/2 mile, turnouts will be provided at 1/4-mile intervals for use by occasional passing or meeting vehicles. Single-lane pavements may be provided for fire lanes and approach drives to buildings within built-up areas, in which case the pavement will be at least 12 feet wide in all cases.

c. Two-lane roads and streets.

(1) Class B, D, and E roads. The bulk of the roads and streets at Army installations are two-lane highways. These include Class B, D, and E roads and Class B, D, and E streets.

(2) Class A, C, and F roads. Road classifications A, C, and F need not be used for mobilization conditions. Class B roads will allow adequate traffic pattern considerations to provide criteria for road design thicknesses commensurate with the 5-year life expectancy of the mobilization program. The use of four lane roads is to be minimized for mobilization construction. Where four lane roads cannot be avoided, Class B criteria will be used. When the road classifications were reviewed in light of mobilization requirements, it was determined that the requirements of Class B roads or Class D roads could be used to satisfy the traffic range of Class C roads. The single lane roads of Class F can readily be designed as minimum Class E roads. By reducing the number of road classifications, the refinement and detail of traffic flow data is greatly reduced without seriously affecting the development of road systems for Army installations under mobilization conditions.

d. Multilane (four traffic lanes or more) highways. The design criteria presented herein for highways are generally applicable to multilane highways also, except that passing sight distance is not required. Where multilane highways are designed for relatively high speeds, opposing traffic should be separated by properly designed medians.

2-3. Design controls.

a. Topography and land use. Tables 1-1 and 1-2 set forth appropriate design standards for roads and streets traversing flat, rolling, or mountainous terrain in built-up or open areas.

b. Vehicle characteristics. Table 2-1 shows dimensions of design vehicles on which the geometric design criteria presented herein are based. Some of these vehicles are wider than 8.5 feet, which is the maximum width shown in table 2-1 for any of the design vehicles. The turning radii and dimensions of special vehicles will be obtained from the Facilities Engineer. Methods for modification of these criteria for use on roads and streets subject to vehicles greater in overall width than 8.5 feet are presented later in this manual.

c. Traffic. The geometric design criteria presented in tables 1-1 and 1-2 have been developed on the basis of horizontal area requirements for various combinations of number and kind of vehicles expected in the traffic stream. The general unit for measurement of traffic is average daily traffic (ADT); the basic fundamental unit of measurement of traffic is design hourly volume (DHV).

(1) Volume. Traffic volumes are expressed as ADT and DHV in tables 1-1 and 1-2. The ADT represents the total traffic volume for the year divided by 365. It is a value needed to determine total service and economic justification for highways but is inadequate for geometric design because it does not indicate the significant variation in the traffic during seasons, days, or hours. If a road or street is to be designed so that traffic will be properly served, consideration must be given to the rush-hour periods. The rush hour volume represented as an average daily peak hour is the basis of the DHV. The DHV is to be used for geometric design. Limited studies made of traffic flows at Army installations indicate that because of the high frequency with which peak hourly traffic occurs, the average daily peak can be economically and efficiently used as the DHV. The DHV in tables 1-1 and 1-2 are shown as 15 and 12 percent, respectively, of the ADT. These are median values selected for Army installations.

(2) Composition. Traffic on installation roads and streets may consist of a combination of passenger cars, light-delivery trucks, single-unit trucks, truck combinations, buses, and half-or full-track tactical vehicles. Trucks, buses, and tracked vehicles have more severe operating characteristics, occupy more roadway space, and

Table 2-1. Design Vehicle Dimensions

Vehicle Type	Vehicle Symbol	Wheel Base	Overhang Front	Overhang Rear	Overall Length	Overall Width	Height	Turning Radius [c]
Passenger	P	11	3	5	19	7	--	24
Single-unit truck	SU	20	4	6	30	8.5	13.5	42
Single-unit bus	BUS	25	7	8	40	8.5	13.5	42
Semitrailer combination								
Intermediate	WB40	13 + 27 = 40[a]	4	6	50	8.5	13.5	40
Large	WB50	20 + 30 = 50[a]	3	2	55	8.5	13.5	45
Full trailer combination	WB60	9.7 + 20 + 9.4[b] + 20.9 = 60	2	3	65	8.5	13.5	45

(All dimensions in feet.)

NOTE: In designs for normal operations, the largest vehicle representing a significant percentage of the traffic should be used. In designing roads or streets to accommodate truck traffic, one of the semitrailer combinations should be used. A design check should be made to insure that the largest vehicle expected to use the road or street can negotiate all turns, particularly if pavements are curbed.

a Length of tractor plus length of trailer.
b Distance between rear wheels of front trailer and front wheels of rear trailer.
c Minimum turning radius outside front wheel.

U. S. Army Corps of Engineers

consequently impose a greater traffic load on highways than do passenger cars and light-delivery trucks. ADT and DHV for various combinations of vehicular traffic are shown in tables 1-1 and 1-2. The larger the proportions of buses, trucks, and tracked vehicles present in the traffic stream during the selected design hour, the greater the traffic load and highway capacity required. The DHV of tables 1-1 and 1-2 diminish for each highway class as the percentage of buses, trucks, and tracked vehicles in the traffic stream increase. The tables provide design data for traffic containing 0, 10, 20, and 30 percent buses, trucks, and tracked vehicles.

2-4. Speed and capacity influence.

a. Speed.

(1) Influence on geometric design. Vehicular speed varies according to the physical characteristics of the vehicle and highway, weather conditions, volume of traffic, and the type of shoulders and other roadside features. On streets, the speed generally will depend on traffic control devices when weather and traffic conditions are favorable. On roads, the physical features of the roadway usually control speed if other conditions are favorable. Therefore, speed is a positive control for geometric design. Consideration must be given to the selected design speed and average running speed if adequate designs are to be developed.

(2) Design speed. The speed selected for design is the major control in designing physical features of highways. Practically all features of a highway will be affected to some extent by the design speed. Maximum curvature, superelevation, and minimum sight distance are automatically determined by the selected design speed. Other features such as pavement and shoulder width, and lateral clearance to obstructions are not directly affected by design speed but do affect vehicle speed. The design speed should be selected primarily on the basis of terrain characteristics, land use, and economic considerations. The geometric design criteria presented herein are based on the design speeds shown under "Design Controls" in tables 1-1 and 1-2.

(3) Average running speed. The average running speeds on which the geometric design criteria are based are shown under "Design Controls" in tables 1-1 and 1-2.

b. Capacity.

(1) Conditions affecting capacity. The capacity of a road or street will vary with lane width, distance to lateral obstructions, condition and width of shoulders, profile and alinement, and with the composition and speed of traffic. These factors are referred to

collectively as prevailing conditions. Those factors depending on physical features of the highway are called prevailing roadway conditions, and those depending on the character of the using traffic are called prevailing traffic conditions. The term capacity in itself has no significance unless the prevailing roadway and traffic conditions are stated.

(2) Capacity analysis. Capacities under ideal conditions are presented in the TRB Highway Capacity Manual. Uninterrupted flow capacities under ideal traffic and roadway conditions for 2-lane, 2-way, highway, (total for both lanes) and for multilane highway (average per lane for direction of heavier flow), will be 2,000 passenger cars per hour.

(3) Capacity for uninterrupted flow. The DHV shown in tables 1-1 and 1-2 are equal to the capacity for uninterrupted flow for each class of road and street on the basis of the geometric design criteria presented. Highway capacity is directly related to the average running speed. Maximum capacity occurs when average running speed is between 30 and 45 mph. Any factors which reduce or increase the average running speed will also reduce capacity. The capacities (DHV) shown in tables 1-1 and 1-2 for Class B roads, and Class B and D streets will be reduced in accordance with the following tabulation in all cases where it is anticipated that the average running speed on a substantial length of a road or street will be appreciably less than 30 mph.

Average Running Speed, mph	Capacity (DHV) in Percentage of Values Shown in Tables 1-1 and 1-2
30	100
25	95
20	87
15	72

CHAPTER 3

GEOMETRIC DESIGN FOR ROADS AND STREETS

3-1. Cross-section elements.

a. Pavement.

(1) Type surface. Pavement type is seldom an important factor in geometric design; however, the ability of a pavement surface to retain its shape and dimensions, its cross-section, and the possible effect of pavement surface on driver behavior should be considered in geometric design.

(2) Normal cross slope. Selection of proper cross slope depends upon speed-curvature relations, vehicle characteristics, curb requirements, and general weather conditions. Cross slope for sharp curves (superelevation) is discussed in AASHTO GD-2. Cross slope on tangents and flat curves are shown in tables 1-1 and 1-2. Where two or more lanes are inclined in the same direction on Class B roads and streets, each successive lane outward from the crown line should have an increased cross slope. The lane adjacent to the crown line should have the minimum cross slope shown in tables 1-1 and 1-2 and the cross slope of each successive lane should be increased 1/16 in/ft. Where pavements are designed with barrier curbs, it is recommended that a minimum cross slope of 3/16 in/ft be used on Class B roads and streets and that a minimum cross slope of 1/4 in/ft be used on Class D and E roads and streets.

b. Lane width. The number and width of traffic lanes shown in tables 1-1 and 1-2 are the minimum considered adequate to accommodate the indicated design hourly volume when the traffic is composed principally of wheeled vehicles whose overall widths are 8.5 feet or less. Wider traffic lanes are required when the traffic is composed of a significant percentage of vehicles whose overall widths are greater than 8.5 feet. In general, the lane width will be increased by the excess width of the largest over-sized vehicle (vehicle width minus 8.5 feet to the nearest higher even foot) where such traffic is anticipated.

3-2. Curbs, combination curbs, and gutters. Curbs, combination curbs and gutters, and paved gutters with attendant storm drainage facilities will not be considered during a mobilization situation unless they are determined to be absolutely necessary or conditions would allow their construction. The road or street design will account for the "no curb" feature and provide for drainage and erosion control accordingly.

a. Curb construction. In built-up areas, curbs, combination curbs and gutters, and paved gutters with attendant underground storm drainage systems will be provided when necessary along streets and in open storage areas as required to aid in the collection and disposal of surface runoff including snowmelt, to control erosion, to confine traffic, or as required in the extension of existing similar facilities. In open areas, combination curbs and gutters will not be provided along roads except where necessary on steep grades to control drainage and prevent erosion of shoulders and fill slopes. Where such facilities are required, they should be located outside the edges of traffic lanes and should be either of the mountable type with suitable outlets and attendant drainpipes or paved gutters with shallow channels extending across the road shoulders and down the fill slopes.

b. Classification and types. Curbs are classified as barrier or mountable according to their intended use. Barrier curbs are designed to prevent or at least discourage vehicles from running off the pavement and therefore have a steeply sloping face at least 6 inches high. Mountable curbs are designed to allow a vehicle to pass over the curb without damage to the vehicle, and have a flat sloping face 3 to 4 inches high. For construction purposes, curbs are usually designated as "combined curb and gutter" and "integral curb and gutter." For Army installations curbs are divided into four types for convenience of reference: Type I is a combined gutter section and barrier curb; Type II is a combined gutter section and mountable curb; Type III is a combined gutter section and offset barrier curb; and Type IV is a barrier curb integral with pavement slab. Curbs should be placed on undisturbed subgrade or subgrade compacted to the same density as subgrade of adjacent road.

c. Location in regard to lane width.

(1) Type I, III, or IV (barrier curbs). It is necessary to offset barrier curbs a sufficient distance from the edge of the nearest traffic lane to prevent reduction in capacity. Curb offset and traffic lane width for classified roads and streets designed with barrier curbs are shown in tables 1-1 and 1-2.

(2) Type II curbs. Mountable curbs cause very little, if any, lateral displacement of traffic adjacent to these curbs; therefore, it is acceptable to locate Type II curbs at the edge of a traffic or parking lane.

3-3. Road and street appendages.

a. Shoulders.

(1) Width. Shoulder widths should be as stated in tables 1-1 and 1-2.

(2) Shoulders for roads. Roads in rural areas are normally designed without curbs and require full width shoulders to accommodate

high traffic volumes. Geometric design criteria for shoulders on roads are presented in table 1-1.

(3) Shoulders for streets. As a general rule, streets in cities are designed with some type of barrier curb and do not require shoulders except where needed for lateral support of the pavement and curb structure. Where lateral support is required, the shoulder should be at least 4 feet in width where feasible. In other sections within built-up areas, where desirable to design streets without barrier curbs, geometric design criteria are presented in table 1-2.

b. Medians.

(1) Uses. Where traffic volume requires construction of multilane highways, opposing traffic should be separated by medians. Medians should be highly visible both day and night, and there should be a definite color contrast between median and traffic lane paving. The absolute minimum width for a median is 4 feet with a desirable minimum width of 14 feet.

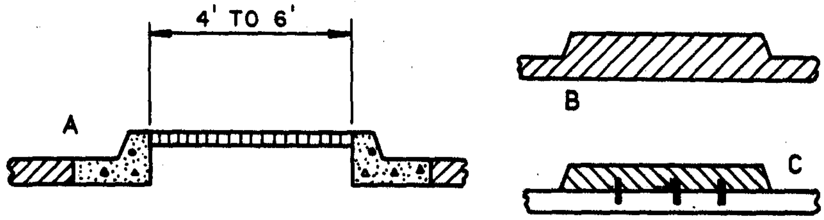
(2) Types. Cross sections of medians are illustrated in figure 3-1. It is not necessary that medians be of uniform width throughout the length of divided highways.

(3) Curbs. All design criteria relative to curbs presented herein are applicable to median curbs.

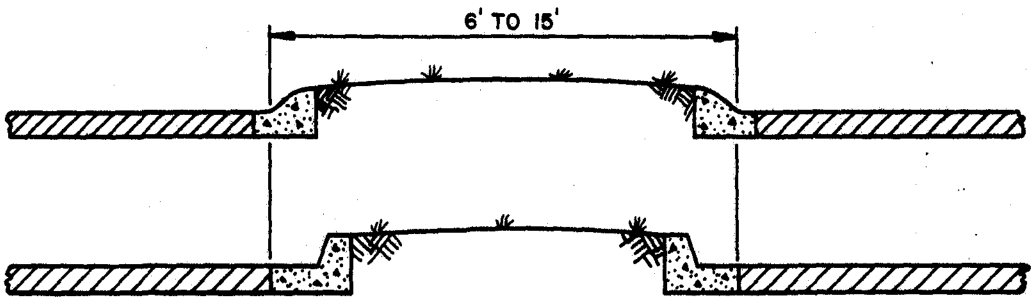
c. Guardrails and guideposts.

(1) Uses. For safety and guidance of traffic, guideposts should be provided at all locations along roadways where drivers may become confused, particularly at night, as to the direction of the roadway; along roadways subject to periodic flooding; along roadways where fog exists for long periods of time; and where driving off the roadway is prohibited for reasons other than safety. Guardrails are normally required at locations where vehicles accidentally leaving the roadway might be damaged, resulting in injury to occupants. Guardrails or guideposts should conform to local highway department criteria.

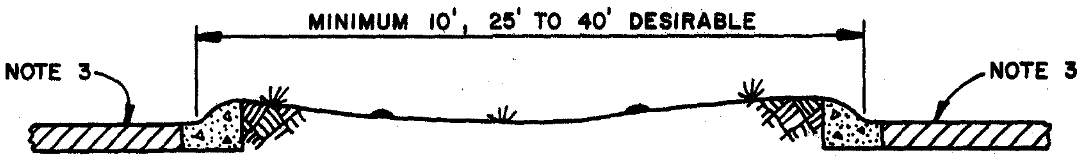
(2) Design criteria. Guardrails or guideposts are not normally required where the front side slopes are 4:1 or flatter. Design criteria for determining where guardrails or guideposts are required is shown by figure 3-2. The ordinate of this figure, designated "Height of Cut or Fill in Feet," is used in this manual to refer to the vertical distance between the outside (intersection of shoulder and front slope planes) edge of the shoulder and the toe of the front slope in cuts and on fills, or between the toe and top of back slope in cuts.



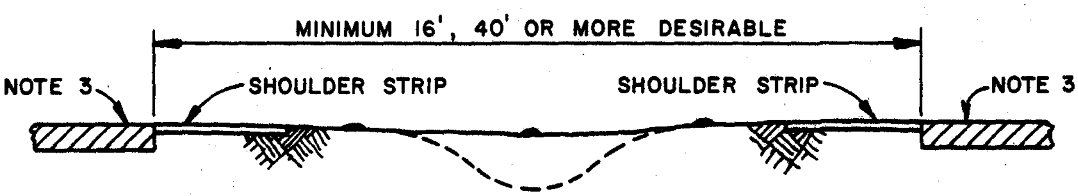
1. CURBED AND CROWNED: PAVED



2. CURBED AND CROWNED: TURF COVER



3. CURBED AND DEPRESSED: TURF COVER



4. FLUSHED AND DEPRESSED; TURF COVER

NOTES:

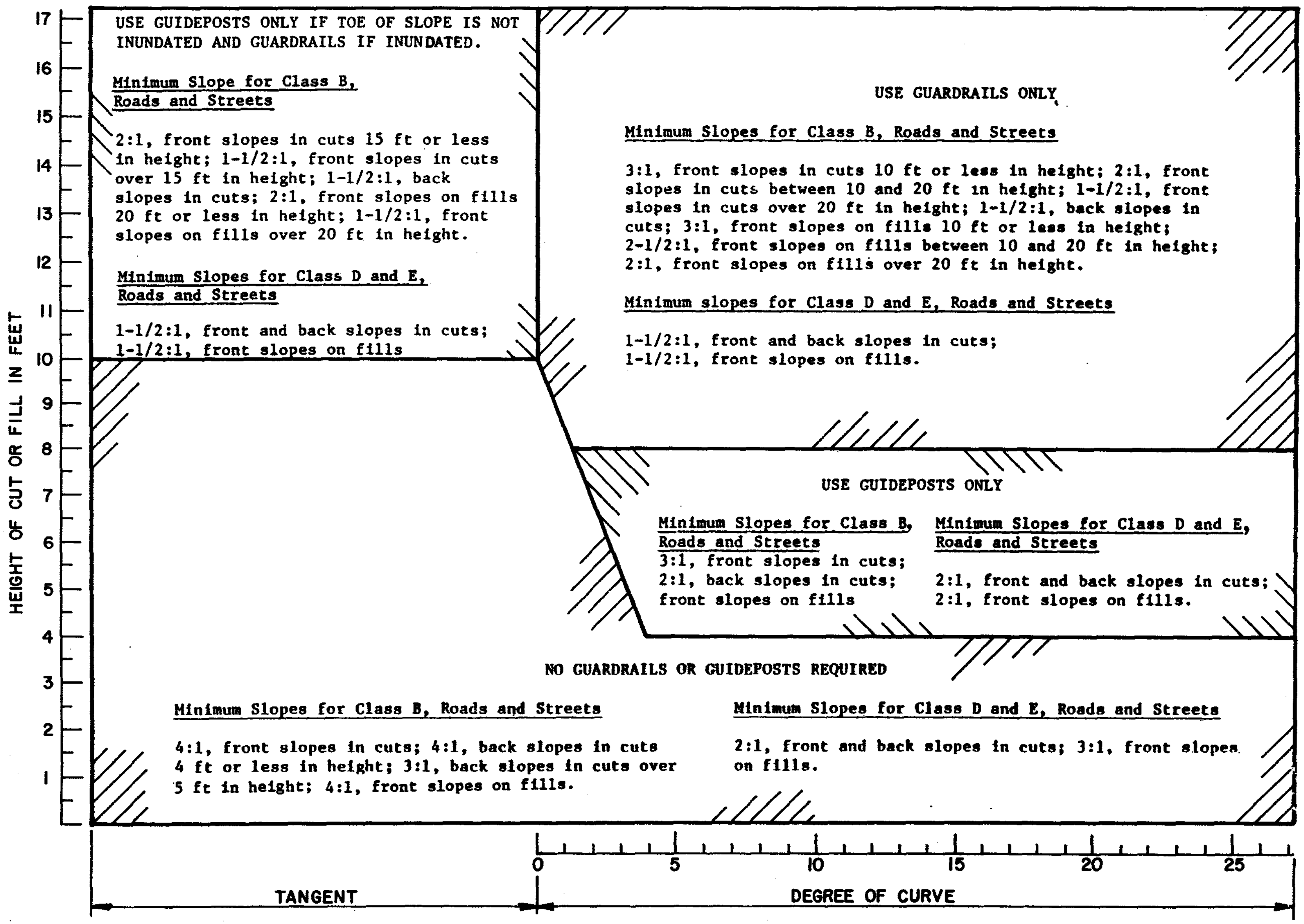
1. Curbs and paved median may be monolithic as in 1-B or may be surface-mounted on monolithic pavement as in 1-C. If surface-mounted, the curb-and-median slab must be anchored or bonded to the pavement (1-C).

2. All medians less than 10 feet wide should be designed with barrier curbs. If vegetation is to be maintained on median, or if snow removal will be required, the minimum width of median should be 10 feet. Separating guardrails will be installed in medians if justified by traffic conditions.

3. Where depressed medians are used for 4-lane highways, opposing lanes are to utilize standard Class B 2-lane roads design.

U. S. Army Corps of Engineers

FIGURE 3-1. CROSS SECTIONS OF GENERAL TYPES OF MEDIANS



NOTES: 1. Generally the depth of cut (see H in figure 3-6) adjacent to roads and streets shall not be greater than 6 ft. below the grade line of the outside edge of the shoulder. Greater depths may be used when specifically approved.
2. Cuts in solid rock or loess should have vertical side walls; therefore, no back slope will be required in these materials.

U. S. Army Corps of Engineers

FIGURE 3-2. DESIGN CRITERIA; GUARDRAILS, GUIDE POSTS, AND EARTH SLOPES

(3) Location with respect to edge of pavement. Guardrails or guideposts should be located at a constant offset from the edge of a pavement outside the limits of the usable shoulder and with an elevation of the base between 4 inches and 9 inches below the edge of the lane pavement. Shoulder widths shown in tables 1-1 and 1-2 will be widened 2 feet to provide space for installation of guardrails or guideposts. Guardrails or alinement of guideposts should be flared outward and, if required, buried on the traffic approach end and tapered in at narrow structures to meet curb lines.

(4) Marking. Guardrails and guideposts must be highly visible, particularly at night. All guardrails and guideposts should be marked or painted in accordance with AASHTO safety requirements.

d. Earth slopes. In determining inclination of side slopes, proper consideration should be given to drainage, maintenance, erosion, and stability. It may be difficult to control erosion of some soils on steep slopes (4:1 or steeper), and it may be impossible to control erosion or maintain vegetation cover on slopes steeper than 2:1. If maintenance is to be accomplished without special equipment, side slopes should not be steeper than 3:1. It is essential that side slopes along highways be flat enough to assure stability under all normal conditions. Design criteria for selecting earth slopes is presented in combination with design policy for establishing need for guardrails and guideposts in figure 3-2.

e. Bridge clearance. Requirements affecting highway safety are found in AASHTO HB-12.

(1) Horizontal. The minimum horizontal distance between curbs on bridges should be equal to the width of the approaching roadway including traffic lanes, parking lanes, full width of shoulders, and medians (on divided highways). When the cost of parapets and railings is less than the cost of decking the median area, traffic lanes for traffic in opposing directions will be on separate structures. It is usually more economical to pave over the median area on bridges with a median width less than about 15 feet.

(2) Vertical. The minimum vertical clearance will be at least 14 feet over all traffic lanes, parking lanes, and shoulders.

3-4. Sight distance. The length of roadway visible ahead of a vehicle along a highway is termed "sight distance." Sight distance is divided into two categories: stopping sight distance and passing sight distance. Minimum stopping and passing sight distances are shown in tables 1-1 and 1-2. Effort should be made to provide sight distances greater than those shown.

a. Stopping sight distance. On single-lane roads, the stopping sight distance must be adequate to permit approaching vehicles each to stop. Horizontal curve sight distance will be critical and will be twice that required for a two or more, lane highway.

b. Passing sight distance. Passing sight distance should be provided as frequently as possible along two-lane, two-way roads, and a length equal to or greater than the minimum values shown in table 1-1 should be provided. The minimum passing sight distances in table 1-1 provide safe distances for a single isolated vehicle traveling at design speed to pass a vehicle going 10 mph less than design speed. Sight distances and safe passing sections should be shown on all construction and improvement plans to aid in proper marking and sign placement.

3-5. Horizontal alinement.

a. General. Where changes in horizontal alinement are necessary, horizontal curves should be used to affect gradual change between tangents. In all cases; consideration should be given to the use of the flattest curvature practicable under existing conditions. Adequate design of horizontal curves depends upon establishment of the proper relations between design speed and maximum degree of curvature (or minimum radius) and their relation to superelevation. The maximum degree of curvature is a limiting value for a given design speed and varies with the rate of superelevation and side friction factors.

b. Maximum curvature.

(1) Roads. Desirable and absolute values for use in design of horizontal curves on superelevated roads are shown in table 1-1. The absolute maximum curvature for roads without superelevation is the same as shown for streets with normal crown sections in table 1-2.

(2) Streets. Absolute maximum values for degree of curvature on streets in built-up areas are shown in table 1-2. Absolute maximum values are given for streets with normal crown sections (no superelevation) and with superelevated sections.

c. Superelevation. A practical superelevation rate together with a safe side friction factor determines maximum curvature. Superelevation rate and side friction factors depend upon speed, frequency and amount of precipitation and type of area, i.e., built-up or open. Superelevation rates will be determined in accordance with AASHTO GD-2.

d. Widening of roads and streets.

(1) Pavements on roads and streets will be widened to provide operating conditions on curves comparable to those on tangents. Widening is necessary on certain highway curves because long vehicles occupy greater width and the rear wheels generally track inside the

front wheels. The added width of pavement necessary can be computed by geometry for any combination of curvature and wheel base. Generally, widening is not required on modern highways with 12-foot lanes and hightype alinement, but for some combinations of speed, curvature, and width, it may be necessary to widen these highways also. The amount of widening required on horizontal curves on roads is shown in table 3-1.

(2) This is the widening normally required for off-tracking and may not provide clearance where sight is restricted. The additional width should be added to the inside of the curve, starting with zero at the TS (tangent-spiral), attain the maximum at the SC (spiral-curve), and diminishing from the maximum at the CS (curve spiral) to zero at the ST (spiral-tangent) as shown in figure 3-3. Increased sight distance may be provided by additional widening or by removal of sight obstructions. The latter is normally recommended because it is generally more economical. Figure 3-4 shows the relation between sight distance along the center line of the inside lane on horizontal curves and the distance to sight obstructions located inside these curves. The clear sight distance along the center line of the inside lane on horizontal curves should equal the minimum stopping sight distance shown in table 1-1 for the design speed.

3-6. Vertical alinement.

a. Grade. Design of vertical alinement involves the establishment of longitudinal grade or slope for roads, streets, and highways. The key considerations for determining grades are speed reduction for maximum grade and drainage for minimum grade.

(1) Determining maximum grade. The maximum allowable grade is dependent on the length the grade is sustained. The critical length of grade is the distance a design vehicle with a 40,000 pound gross weight and a 100-hp engine can travel up a designated grade before speed is reduced below an acceptable value (usually 30 mph). Critical lengths for grades are shown in tables 1-1 and 1-2. If a grade exceeds critical length, highway capacity is reduced unless a climbing lane is added for heavy vehicles.

(2) Determining minimum grade. Tables 1-1 and 1-2 give minimum grades which are adequate for proper drainage.

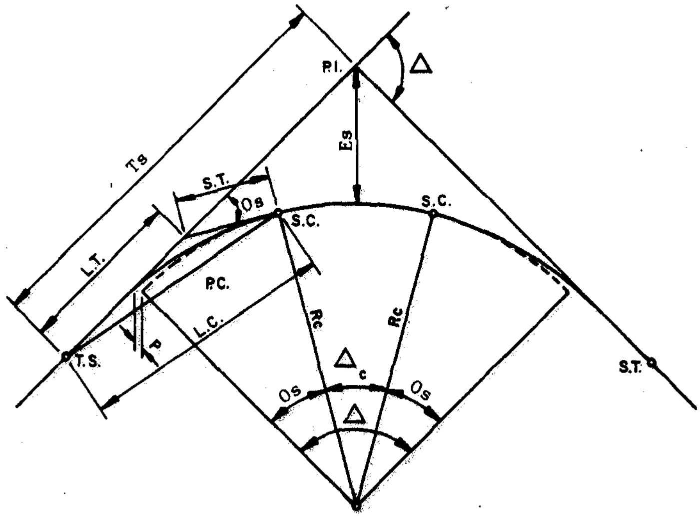
b. Curves. Generally, vertical curves should be provided at all points on roads or streets where there is a change in longitudinal grade. The major control for safe vehicle operation on vertical curves is sight distance, and the sight distance should be as long as possible or economically feasible. Minimum sight distance required for safety must be provided in all cases. Vertical curves may be any one of the types of simple parabolic curves shown in figure 3-5. There are three length categories for vertical curves: maximum, length required for safety, and minimum. All vertical curves should be as long as

Table 3-1. Calculated and Design Values for Pavement Widening on Roads and Streets Within Army Installations 2-Lane Pavements, One-Way or Two-Way

Degree of Curve	Widening, in Feet, for 2-Lane Pavements on Curves for Width of Pavement on Tangent of: 24 feet, Design speed, mph						22 feet, Design speed, mph					20 feet, Design speed, mph			
	30	40	50	60	70	80	30	40	50	60	70	30	40	50	60
1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	1.0	1.0	1.5	1.5	1.5	2.0
2	0.0	0.0	0.0	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	2.0	2.0	2.0	2.5
3	0.0	0.0	0.5	0.5	1.0	1.0	1.0	1.0	1.5	1.5	2.0	2.0	2.0	2.5	2.5
4	0.0	0.5	0.5	1.0	1.0		1.0	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0
5	0.5	0.5	1.0	1.0			1.5	1.5	2.0	2.0		2.5	2.5	3.0	3.0
6	0.5	1.0	1.0	1.5			1.5	2.0	2.0	2.5		2.5	3.0	3.0	3.5
7	0.5	1.0	1.5				1.5	2.0	2.5			2.5	3.0	3.5	
8	1.0	1.0	1.5				2.0	2.0	2.5			3.0	3.0	3.5	
9	1.0	1.5	2.0				2.0	2.5	3.0			3.0	3.5	4.0	
10-11	1.0	1.5					2.0	2.5				3.0	3.5		
12-14.5	1.5	2.0					2.5	3.0				3.5	4.0		
15-18	2.0						3.0					4.0			
19-21	2.5						3.5					4.5			
22-25	3.0						4.0					5.0			
26-26.5	3.5						4.5					5.5			

NOTES: Values less than 2.0 may be disregarded.
3-lane pavements: multiply above values by 1.5.
4-lane pavements: multiply above values by 2.
Where semitrailers are significant, increase tabular values of widening by 0.5 for curves of 10 to 16 degrees, and by 1.0 for curves 17 degrees and sharper.

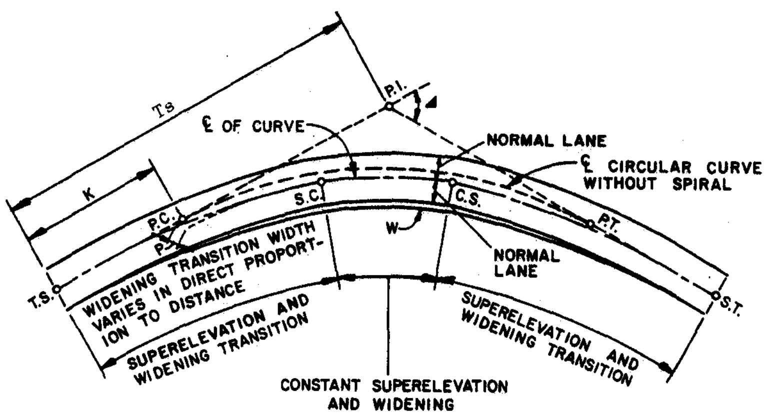
HORIZONTAL CURVES WITH TRANSITION SPIRALS — BOTH ENDS



TRANSITION SYMBOLS

P.I. -Point of intersection of main tangents.
T.S. -Common point of tangent and spiral.
&S.T. Spiral and tangent.
S.C. -Spiral curve, common point of spiral and circular curve of near transition.
C.S. -Curve spiral, common point of circular curve and spiral of far transition.
Rc -Radius of circular curve.
Ls -Length of spiral between T.S. and S.C.
Ts -Tangent distance P.I. to T.S. or S.T, or Tangent distance of the complete curve.
L.C. -Straight Line Chord distance T.S. to S.C.
K -Distance from T.S. to point on tangent opposite the P.C. of the circular curve produced.

Es -External distance P.I. to center of circular curve portion.
L.T. -Long tangent distance of spiral only.
S.T. -Short tangent distance of spiral only.
P -Offset distance from the tangent of P.C. of circular curve produced.
Δ -Intersection angle between tangents of entire curve.
Δ c -Intersection angle between tangents at S.C. and at the C.S. or the central angle of the circular curve portion of the curve.
Os -Intersection angle between the tangent of the complete curve and the tangent at the S.C., The spiral angle.
W -Widening



To locate spiral transition, use tables as given in Transition Curves for Highways, (See appendix A, Government Depository Libraries)

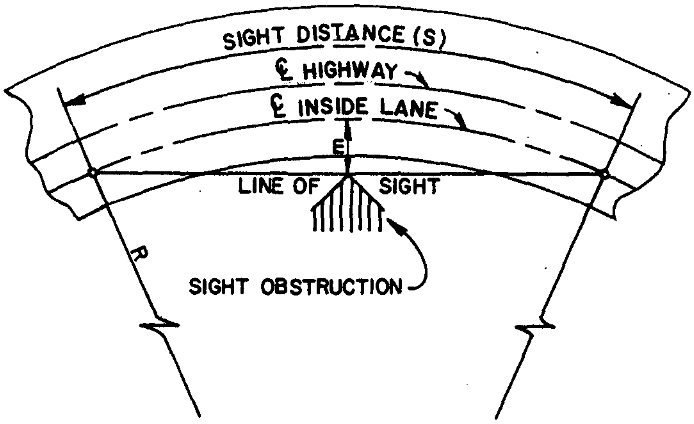
U. S. Army Corps of Engineers

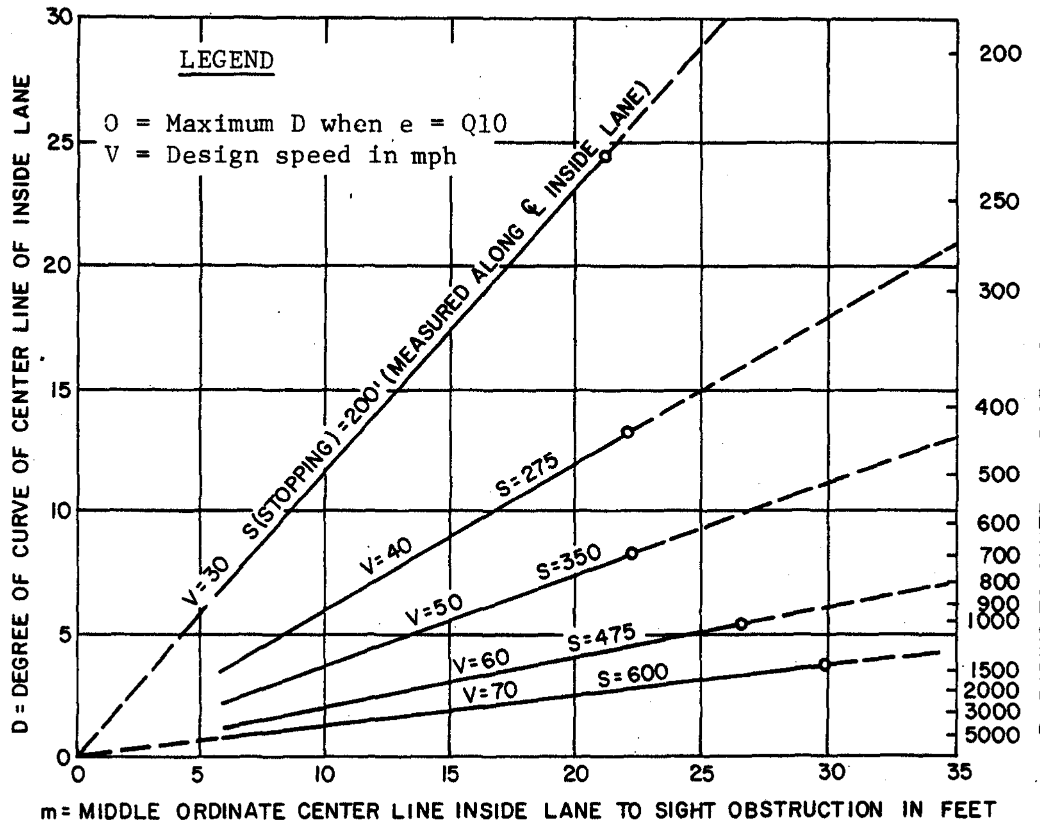
FIGURE 3-3. METHOD OF LAYOUT OF WIDENING AND SUPERELEVATION OF SPIRAL LANES

$$m = \frac{5730}{D}\ \text{VERS}\ \frac{50}{200}$$

$$\text{Also } m = R\left(\text{VERS } \frac{2865S}{R}\right)$$

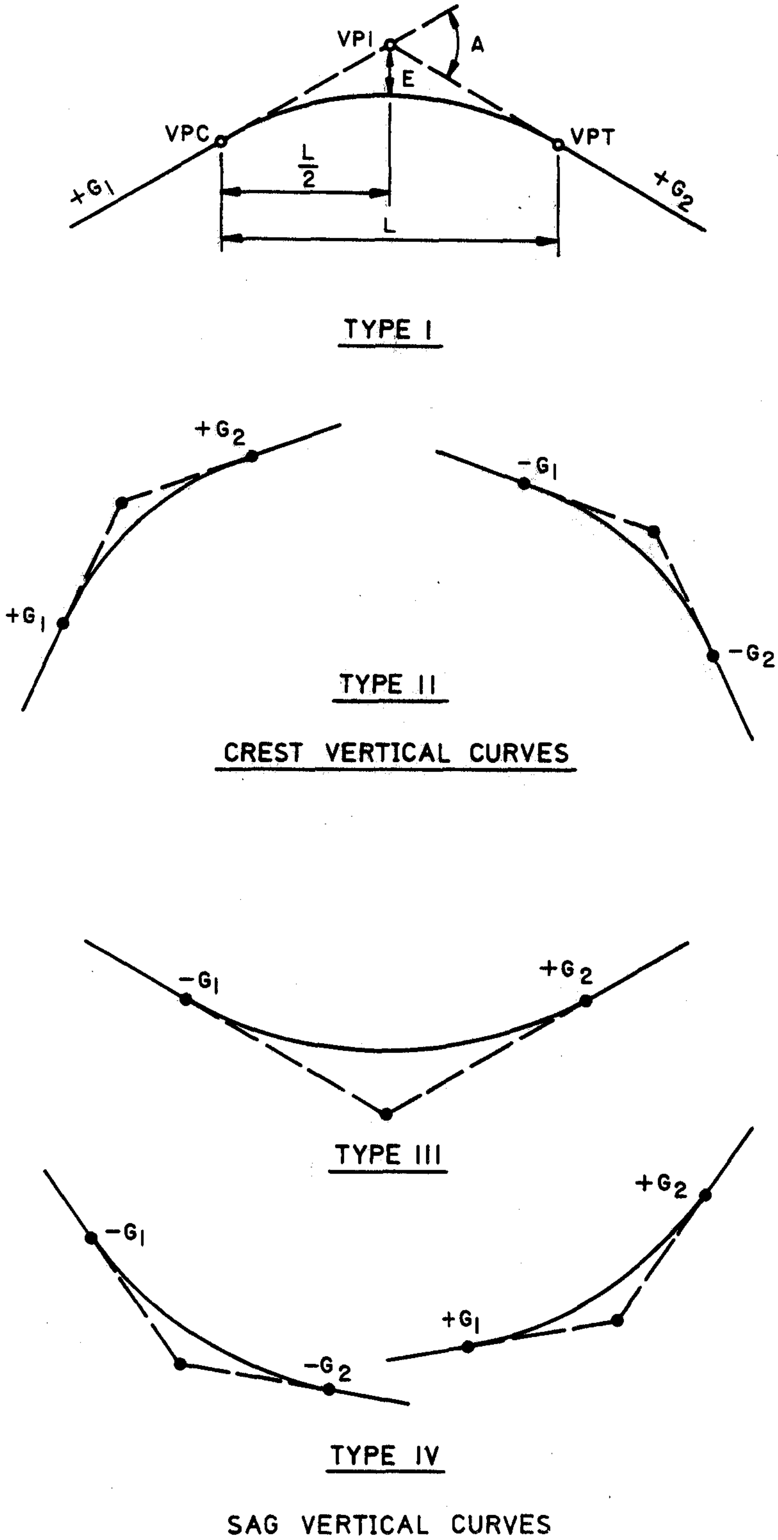
$$\text{And } S = \frac{R}{2865}\ \cos^{-1}\left(\frac{R-m}{R}\right)$$





U. S. Army Corps of Engineers

FIGURE 3-4. STOPPING SIGHT DISTANCE ON HORIZONTAL CURVES, OPEN ROAD CONDITIONS



U. S. Army Corps of Engineers

FIGURE 3-5. TYPES OF VERTICAL CURVES

economically feasible. The minimum length of vertical curves is also shown in tables 1-1 and 1-2.

3-7. Cross section. Figures 3-6 and 3-7 illustrate typical combinations of cross-section elements for which geometric design criteria are outlined in tables 1-1 and 1-2. Other combinations of these cross-section elements are illustrated in AASHTO GU-2.

a. Roads.

(1) Normal-crown section. The typical road-type, normal-crown cross section shown in figure 3-6 comprises the so-called "streamlined" cross section. Shoulder edges, channel bottoms, and the intersection of side slopes with original ground are rounded for simplification of maintenance and appearance. On roads in open areas rounding of shoulder edges will be restricted to a strip 3 to 4 feet wide at the intersection of slopes steeper than 2-1/2:1, and only slight rounding will be used at intersections of slopes flatter than 2-1/2:1.

(2) Superelevated section. Figure 3-6 shows the preferable superelevated cross sections for roads at Army installations. The low side of this cross section is similar to a normal-crown section except that the shoulder slope on the low side of the section is the same as the pavement superelevation, except where normal slope is greater. On the high side of a superelevated section the algebraic difference in cross slopes at the pavement edge should not exceed about 0.07. The vertical curve should be at least 4 feet long, and at least the inside 2 feet of the shoulder should be held on the superelevated slope.

b. Streets. Typical street-type cross sections with and without parking are shown in figure 3-7. Geometric design for the various cross-section elements shown are presented in table 1-2.

3-8. Intersection criteria.

a. General. Practically all highways within Army installations will intersect at grade, and normally the designer will need to consider only plain unsignalized or signalized intersections. Intersections are normally closely spaced at regular intervals along streets in built-up areas, and the capacity of these streets will in most cases be controlled by intersection capacity.

b. Design criteria. Geometric design criteria for intersections are presented in AASHTO GD-3, GU-2, SR-2 and the TRB Highway Capacity Manual.

c. Army installation areas equivalent to design criteria areas. Variations in average intersection capacities on one-way and two-way streets subject to fixed time signal control are shown for general types of areas within cities in the TRB Highway Capacity Manual. The curves used at a particular location on Army installations should be

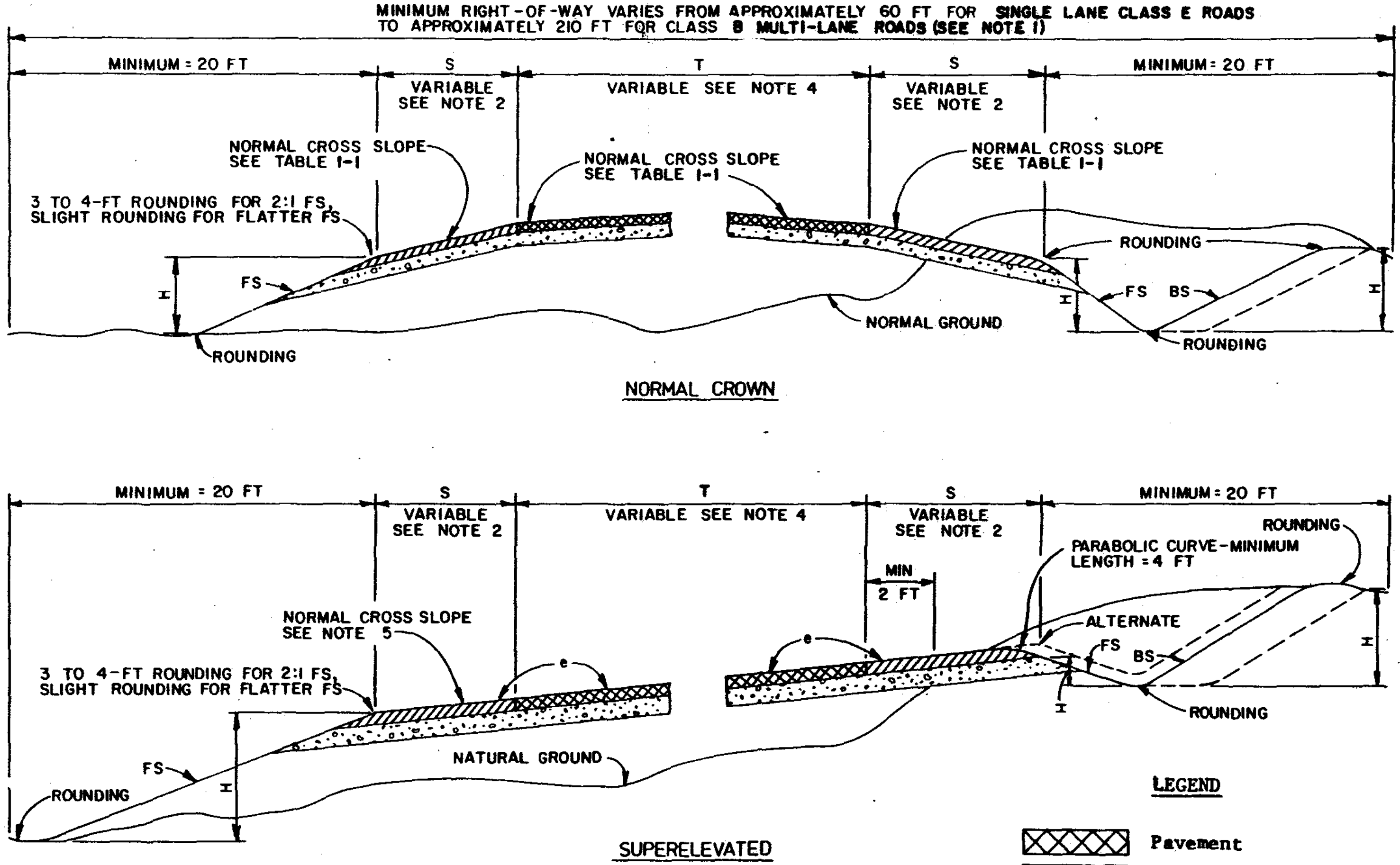


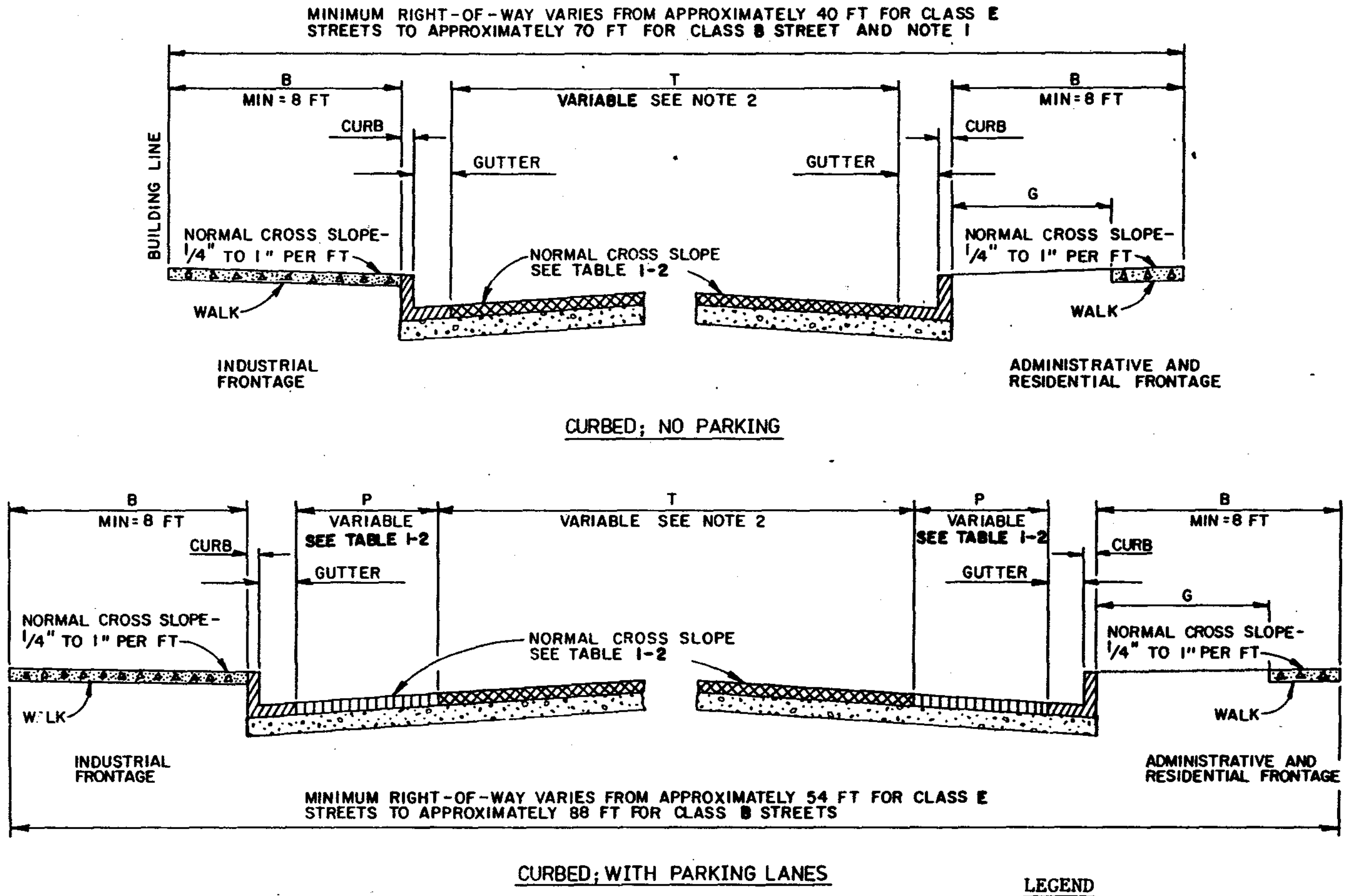
FIGURE 3-6. TYPICAL ROAD-TYPE CROSS SECTIONS

LEGEND

(crosshatch)	Pavement
(diagonal hatch)	Shoulder
(stipple)	Base Course
FS	Front Slope
BS	Back Slope
H	Height of cut or fill
S	Width of shoulder
T	Total width of traffic lanes
e	Superelevation rate

NOTES:

1. Variations in cross section and right-of-way are shown in AASHTO GD-2
2. The width of usable shoulders required varies with road classification, steepness of front slopes and guardrail or guidepost locations, see **table 1-1.**
3. Steepness of front and back slopes varies with H as shown in **figure 3-2.**
4. T varies with road classification. Traffic composition and type curb used in design see **table 1-1.**
5. Use superelevation rate e where greater than normal cross slope.
6. **See note 1, figure 3-2 for maximum value of H.**



LEGEND

- Traffic Lane Pavement
- Curb
- Walk
- Base Course
- Parking Lane Pavement
- T Total Width of Traffic Lanes
- B Border
- G Turfed Area (Grassed Area)
- P Parking Lane

NOTES: 1. Dimensions of elements of cross sections now shown on this figure are shown in **table 1-2**.

2. T varies with street classification traffic composition, and type curb used in design.

FIGURE 3-7. TYPICAL STREET-TYPE CROSS SECTIONS selected on the basis of similarity with the type of area indicated in the TRB Highway Capacity Manual. The following tabulation indicates areas in which the intersection curves should normally be used.

Area Designation Used in Highway Capacity Manual	Equivalent Area at Army Installations
Downtown	Central portion of built-up areas at major installations
Fringe, business district	Central portion of built-up areas at all but major installations. Industrial, service, and warehouse areas at major installations.
Outlying business district and intermediate residential	Residential portion of built-up areas at major installations. Industrial, service, warehouse, and residential portions of built-up areas at intermediate installations. All built-up areas at small installations, isolated shopping centers, community centers, and similar areas of public assembly in open areas. Isolated road intersections in open areas.
Rural	TRB Highway Capacity Manual.

3-9. Capacity of intersections. The capacity (DHV) shown in tables 1-1 and 1-2 is for free-flowing highways without intersections at grade or with few crossroads and minor traffic. These highways have no traffic control signals at intersections (plain unsignalized intersections), and capacity is affected very little and uninterrupted flow is assumed. The AASHTO procedure is suggested as a guide in design of intersections.

AASHTO Suggested Design Hourly Volume Combinations for Which Signal Control Should be Assumed in Geometric Design of Intersections.

Type of Intersection	Minimum Two-Way DHV		
2-lane through highway	400	500	650
Crossroad	250	200	100
4-lane through highway	1,000	1,500	2,000
Crossroad	100	50	25

This tabulation may serve as a general guide for design of at-grade intersections in the following manner. If the DHV of traffic at a given intersection is approximately equal to or less than that shown in the tabulation, capacity of the through highway is based on the DHV shown in tables 1-1 and 1-2, and no intersection capacity analysis is required. If the DHV of traffic is greater than that shown in this tabulation, the intersection should be designed as if it were under signal control. The geometric layout should be made in conjunction with an intersection capacity analysis, as in the Highway Capacity Manual. The volumes shown in this tabulation have no relation to warrants for signalization, nor are they indicative of whether or not signalization should be used. Warrants for traffic control signals are given in ANSI D6.1.

3-10. Intersection curves.

a. Minimum edge of pavement design. Where it is necessary to provide minimum space for turning vehicles at unsignalized at-grade intersections, the AASHTO design criteria presented in GU-2 and SR-2 should be used. The minimum radius for edge of pavement design on street intersections is 30 feet, which is required for passenger (P) cars on 90-degree turns. A larger radius should be used if any truck traffic is expected or turning speeds greater than 10 mph are anticipated. The minimum radius on road intersections is 50 feet.

b. Minimum curb radii. Minimum curb radii are normally used at plain unsignalized intersections to reduce intersection area and minimize conflict between pedestrians and vehicles. The curb design should fit the minimum turning path of the critical design vehicle expected in the traffic. Generally, the minimum curb radii to be used on intersection curves may be determined on the basis of the following information.

(1) Curb radii of 15 to 25 feet are adequate for P design vehicles and should be used on Classes D and E cross streets where practically no single unit (SU) truck, WB40, WB50, and WB60 (semitrailer combination trucks) design vehicles are expected or at major intersections where parking is permitted on both intersecting streets. Radii of 25 feet should be provided on all new construction and on reconstruction where space is available.

(2) Curb radii of 30 feet or more should be provided at all major highway intersections to accommodate an occasional truck in the traffic. (See table 2-1 for minimum turning radius.)

(3) Radii of 40 feet or more, preferably three-centered compound curves, to fit the path of the critical design vehicle expected in the traffic, should be provided where SU, WB40, WB50, and WB60 design vehicles turn repeatedly. (See table 2-1 for minimum turning radius.)

3-11. Miscellaneous.

a. Signing. Signs should conform with ANSI D6.1 standards.

b. Pavement markings. Marking should be provided on paved surfaces as a safety measure and to increase orderly traffic flow. Markings should conform to local highway practice criteria. Standard requirements are provided in ANSI D6.1 on uniform traffic control devices.

CHAPTER 4

GEOMETRIC DESIGN FOR WALKS AND OPEN STORAGE AREAS

4-1. Walks.

a. Need. Walks and walkways could be non-essential items during an emergency situation and hence, should not be considered unless deemed necessary or circumstances allow for their construction.

b. Criteria. Smooth, hard-surface walks should be provided to accommodate pedestrian traffic. However, gravel, stone slab, wood or other type walk materials could be utilized if they are readily available.

c. Geometric design. Safety and volume of pedestrian traffic are the primary controls for geometric design of walks. A design pedestrian traffic volume (pedestrians per hour) must be estimated on the basis of available data, engineering judgment, and pedestrian traffic at existing similar installations.

d. Width. The minimum width for walks at Army installations will be 3 feet. Walks will normally be in increments of 2 feet (width of pedestrian traffic lane) as required to accommodate the anticipated volume of pedestrian traffic. An extra foot of width should be added to walks adjacent to curbs or where obstacles encroach on the walk. Width of walks will be determined on the basis of the capacities (pedestrians per hour) shown in the following tabulation:

Capacity of Walks in Pedestrians per Hour	Minimum Width, ft
Less than 10	3
Up to 100	4
100 to 750	6
100 to 1,000	6
Greater than 750	8
Greater than 1,000	10

e. Grade. The grade of walks should follow the natural grade of the ground as nearly as possible. The transverse grade will not be less than 1/4 in/ft. The longitudinal grade should not be greater than about 15 percent. Steps will be used where the maximum longitudinal slope would otherwise be too great. Steps should be grouped together, rather than spaced as individual steps, and located so that they will be lighted by adjacent street or night lights. The sum of the depth of tread and height of riser should not be less than 18 inches and risers should not be less than 5 inches or greater than 7 inches on any steps.

4-2. Open storage areas and parking.

a. General. This section deals with geometric design criteria for parking lots, motor pools, organizational motor parks, material storage areas, utility yards, and miscellaneous repair yards. Storage of explosives or fuels require special conditions and are not included in open storage.

b. Parking lots, motor pools, and repair areas. Traffic volume and mix are the primary considerations in the selection of type of surfacing. It is essential to determine the number of vehicle passes and the traffic patterns of the various types of vehicles under consideration. Special consideration should be given to pavements subject to repeated traffic of track-type vehicles or where fuel and lubricant spillage may occur. The minimum traffic volumes considered for parking lots, motor pools, or repair areas should be equivalent to Class E streets (See table 1-2). Where applicable, design criteria of state or local regulatory agencies may be utilized. Where massive parking is necessary, cross traffic connections should be provided at about 360 foot (40 stalls) intervals. Islands or medians may not be practical under mobilization conditions, however wooden barriers (power poles), railroad ties, or precast concrete bumpers can be used to organize and control traffic and to protect adjoining areas at edge of pavements. Minimum grades should be provided to allow drainage of the areas. Natural drainage to the perimeter of the paved area is preferred; inlets for drainage within the paved area will be avoided to the greatest extent possible. A maximum slope of 5 percent may be used in parking lots, motor pools, and repair areas without restriction of traffic direction or parking angle.

c. Material storage areas. Suitable areas for the storage of goods and materials that do not require extensive protection from the elements will be required at nearly all types of Army installations. In general, these areas will be of an improved type with the area graded to allow good drainage, the subgrade and base course prepared, and a hard surface provided. Semi-improved areas where no hard surface is included may be used under special conditions; however, reduced bearing capacity and potential material handling equipment problems will restrict the use of this type of area. Unimproved areas where no grading for drainage or hard surfaces are provided may be acceptable for materials during construction but should not be considered as Army installation open storage.

(1) Shipping and receiving. A space for loading and unloading will be provided the extent of which will be a function of volume of materials handled and the method of delivery. Minimum provisions will be space for a tractor-trailer to be unloaded by a fork lift truck. Where a railroad siding is included or where high volumes of truck deliveries are anticipated, rail siding platforms will be provided.

(2) Arrangement of storage. Detailed arrangement of storage areas will be a function of type and volume of material, storage time per item, material handling equipment used, and storage inventory procedures. In general though, efficient layouts provide for straight-line flow of material from loading/unloading areas to storage, ready access to each material storage location and efficient use of aisles. Aisles will essentially be roads and should be designed as such for dimensions and traffic flow.

(3) Lines and grades. Storage areas will have minimum slopes consistent with good drainage. Area drains and inlets within the limits of the pavement will be avoided to the greatest extent possible. Surface smoothness on hard surface pavements, will not exceed 3/8 inch deviation from a straightedge laid diagonally across the space of a single storage element (pallet, drum, packing crate, etc.). Where semi-improved storage areas are provided, the deviation from a straightedge should not exceed 5/8 inch. The difference in elevation of the highest and the lowest point of any single storage space (based on a 4 foot square pallet) should not exceed 1-1/2 inches when materials are stacked 15 feet or higher, nor should the slope of the overall storage area exceed 3 percent grade. Where material is stacked less than 15 feet high, a single space differential of 2-1/2 inches and an overall slope of 5 percent grade may be permitted. The use of containerized storage for Army installations other than ports or depots is expected to be limited. See EM 1110-3-150 for special requirements of container handling and storage if required.

(4) Selection of hard surface pavements. The factors that affect the surfacing requirements of improved open storage areas include vehicle characteristics, traffic volume and flow patterns, material accessibility, and weight requirements of the stored material. There are two types of surfaces that are frequently used on improved storage areas: flexible pavements (EM 1110-3-131) and rigid pavements (EM 1110-3-132). Rigid pavement applications are better suited in areas where temperature fluctuations are extreme; however they are labor intensive with longer construction times and are generally more expensive. Flexible pavements are more commonly used but may be limited by material availability. Steel mat may be selected for short term use as an expedient surfacing method. Minimum design considerations should be based on traffic flows for Class E streets (see table 1-2) and/or a minimum static load from material of 1,500 psf. The use of both rigid and flexible pavements may be considered, such as flexible pavement for storage and concrete for aisles and special areas; however, design and construction time constraints as well as material availability must be considered.

(5) Lighting. General area lighting of 1/2 foot-candle at ground level uniformly distributed over the entire storage area should be considered the minimum lighting level. Additional lighting must be considered where night operations are anticipated.

(6) Fire protection. While open storage areas are not normally considered as high a risk as conventional warehousing, proper fire protection is still a major consideration.

(7) Outdoor sports and recreation areas. Sports fields and recreation areas requiring hard surfaces will follow the minimum criteria indicated for open storage. Slopes of pavement and lighting of areas will be in keeping with the requirement of the sport involved.

APPENDIX A

REFERENCES

Government Publications.

Department of the Army.

EM 1110-3-131	Flexible Pavements for Roads, Streets, Walks, and Open Storage Areas.
EM 1110-3-132	Rigid Pavements for Roads, Streets, Walks, and Open Storage Areas.
EM 1110-3-136	Drainage and Erosion Control.
EM 1110-3-150	Storage Depots.

Government Depository Libraries

Transition Curves for Highways (1958), Catalog No. A22.2:H53/7*

Nongovernment Publications.

American Association of State Highway and Transportation Officials (AASHTO), 444 North Capital, N.W., Suite 225 Washington, D.C. 20001

GD-2	Policy on Geometric Design of Rural Highways (1965).
GU-2	Policy on Design of Urban Highways Arterial Streets (1973).
HB-12	Standard Specifications for Highway Bridges. (Including ISB-78, ISB-79, ISB-80, and ISB-81) (1977).

*No longer in print. Originally published by U.S. Department of Agriculture, Bureau of Public Highways. Now available for examination at selected Government Depository Libraries.

SR-2 (1974) Highway Design and Operational Practices Related Highway Safety.

American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018

D6.1-1978 Uniform Traffic Control Devices for Streets and Highways.

Transportation Research Board (TRB), 2101 Constitution Avenue N.W., Washington, D.C. 20418

Highway Capacity Manual.