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GENERAL PROVISIONS AND GEOMETRIC DESIGN FOR ROADS, STREETS, WALKS, AND OPEN STORAGE AREAS

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GENERAL PROVISIONS AND GEOMETRIC DESIGN FOR ROADS, STREETS, WALKS, AND OPEN STORAGE AREAS

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CHAPTER 1
INTRODUCTION

1-1. Purpose and scope. This manual establishes general provisions and geometric design criteria for guidance in the design of roads, streets, walks, and open storage areas at military installations.

1-2. Definitions. The definitions presented below are included to prevent misunderstanding and confusion resulting from the wide variation in meaning of various terms in local, regional, and general use. More comprehensive lists of definitions are presented in the manuals of the American Association of State Highway and Transportation Official (AASHTO) and the Transportation Research Board.

a. Public way and storage area designations.

(1) *Highway.* A general term denoting a public way for purpose of vehicular travel including the entire area within the right-of-way.

(2) *Road.* A term applied to highways in open areas. Open areas are defined in i.(2) below.

(3) *Street.* A term applied to highways in built-up areas. Built-up areas are defined in i.(1) below.

(4) *Walks.* Graded strips between buildings and other facilities adequately surfaced for all-weather use by pedestrians.

(5) *Open storage areas.* Areas planned and designed for storing, servicing, and parking of organizational vehicles; or for parking of visitors' vehicles, civilian employees, and attached personnel; or for receiving, classifying, and storing of supplies, new and salvaged materials, and equipment pending assignment for use or distribution; or for salvaging, processing, or repairing of equipment.

(6) *Hardstand.* Paved portions of open storage areas excluding roadways or service traffic lanes.

b. Highway designations. Highways can be designated according to location: access, replacement, and installation; cross-section design: undivided and divided; or directional usage: one-way and two-way.

(1) *Access.* An access highway is an existing or proposed public highway which is needed to provide highway transportation services from a military reservation to suitable transportation facilities. This will not include installation highways within the boundary of a military reservation that has been dedicated to public use if reasonable assurance can be given that future closure to public use will not be required.

(2) *Replacement.* A replacement is a public highway that must be constructed to replace a public street or road that has been or will be closed to-public use because of the construction or expansion of a military installation or because of security restrictions.

(3) *Installation.* Installation highways include all roads and streets within the site limits of military 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.

(4) *Undivided.* An undivided road or street is a roadway having no natural or structural barrier separating traffic moving in opposite directions.

(5) *Divided.* A divided highway is a two-directional roadway having a natural or structural barrier separating traffic moving in opposite directions.

(6) *One-way.* A one-way road or street is one on which the movement of traffic is confined to one direction.

(7) *Two-way.* A two-way road or street is one on which traffic may move in opposing directions simultaneously. It may be either divided or undivided.

c. Installation highway designations. Installation highways will be divided into four general classifications (primary, secondary, tertiary, and patrol roads) in regard to their relative importance, and will be further classified for design and planning purposes into classes A through F in accordance with topography, land use, speed, volume, and composition of traffic as shown in tables 1-1 and 1-2.

(1) *Primary.* Primary highways, designated by the letter "P," include all installation roads and streets which serve as the main distributing arteries for all traffic originating outside and within an installation and which provides access to, through, and between the various functional areas.

(2) Secondary. Secondary highways, designated by the letter "S," include all installation roads and streets which supplement the primary highway system by providing access to, between, and within the various functional areas.

(3) *Tertiary.* Tertiary highways, designated

Design Controls and Elements	Class A Street* Four-Lane Street Flat	Class A Street* Four-Lane Street Rolling	[illegible] Two-Lane Street Flat	[illegible] Two-Lane Street Rolling	[illegible] Two-Lane Street Flat	[illegible] Two-Lane Street Rolling	[illegible] Two-Lane Street Flat	[illegible] Two-Lane Street Rolling	[illegible] Two-Lane Street Flat	[illegible] Two-Lane Street Rolling	[illegible] Two-Lane Street Flat	[illegible] Two-Lane Street Rolling
Design Controls:												
Traffic composition[1]												
T = 0% DHV[2]	≥1,200	≥1,200	1,000-1,199	1,000-1,199	750-999	750-999	250-749	250-749	25-249	25-249	Under 25	Under 25
T = 10% DHV[3]	≥1,090	≥920	910-1,089	770-919	680-909	580-769	230-679	190-579	23-229	19-189	Under 23	Under 19
T = 20% DHV[3]	≥1,000	≥760	830-999	625-759	620-829	470-624	220-619	160-469	21-219	16-159	Under 21	Under 16
T = 30% DHV[3]	≥920	≥640	780-919	560-639	580-779	400-559	190-579	130-399	19-189	13-129	Under 19	Under 13
Design speed, mph	60	50	50	40	50	40	40	30	40	30	40	30
Average running speed, mph	38	36	36	32	36	32	32	25	32	25	32	25
Cross-Section Elements:												
Pavements:												
Minimum width of lanes, ft[4]												
With barrier curbs Traffic	12	12	12	12	12	12	11	11	10	10	10	10
Parking[5]	None	None	None	None	10	10	8	8	8	8	8	8
Without barrier curbs Traffic	12	12	12	12	12	12	11	11	10	10	10	10
Minimum distance between barrier curbs, ft[4,6]												
With parking lanes[5]	None	None	None	None	47	47	41	41	36	36	36	36
Without parking lanes[7]	33	33	29	29	28	28	25	25	20	20	20	20
Desirable lateral clearance to obstructions, ft[8]	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Normal cross slope, in./ft			1/8 to 1/4				3/16 to 3/8				1/4 to 1/2	
Curbs:[9]												
Types					See paragraph 3-3.c.(3) of this manual							
Offset for barrier curbs, ft	2.5	2.5	2.5	2.5	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5

(Continued)

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% 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 DHVs 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 3-3.c.(2) of this manual. Traffic lanes of streets without curbs in warehouse areas shall not be less than 12 ft regardless of class. The total width of streets with curbs adjacent to warehouses shall 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 3-3.c.(2) for policy relative to provision of parking facilities.
6 Distance shown is the minimum distance between face of curbs.
7 Where Class E or F streets are designed with barrier curbs, curb offsets are not required adjacent to traffic lanes.
8 1.5 feet if curbs are not provided; see note 9.
9 Generally, barrier curbs will be provided on streets in built-up areas. See paragraph 3-3.c.(3) of this manual for "policy" on provision of curbs within built-up areas at military 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.
* The DHV is given in vehicles per hour per lane for direction of heavier flow.
** The DHV is given in total vehicles per hour for all lanes in both directions.

Table 1-1. Geometric design policies for classified roads within “open” areas of military installation

Design Controls and Elements	Class A Road Four-Lane Road			Class B Road Two-Lane Road			Class C Road Two-Lane Road			Class D Road Two-Lane Road			Class E Road Two-Lane Road			Class F Road Single-Lane Road		
	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous
Cross-Section Elements (Continued):																		
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 3-3								
Bridge clearance										See paragraph 3-3.c.(8) of this manual								
Design Elements:																		
Sight distance:																		
Minimum stopping sight distance, ft	600	475	350	600	475	350	475	350	350	415	310	240	415	310	240	400	300	200
Minimum passing sight distance, ft				2,300	2,000	1,700	2,000	1,700	1,700	1,850	1,500	1,050	1,850	1,500	1,050			
Horizontal alignment:																		
Horizontal curves, maximum curvature																		
Desirable maximum	1°30'	2°00'	3°00'	1°30'	2°00'	3°00'	2°00'	3°00'	4°00'	2°30'	3°30'	6°00'	2°30'	3°30'	6°00'	8°00'	8°00'	12°00'
Absolute maximum[10]																		
Where snow and ice are not factors	4°00'	5°30'	8°00'	4°00'	5°30'	8°00'	5°30'	8°00'	8°00'	7°00'	10°30'	18°00'	7°00'	10°30'	18°00'	25°00'	36°00'	58°00'
Where snow and ice are factors	3°00'	4°30'	7°00'	3°00'	4°30'	7°00'	4°30'	7°00'	7°00'	5°45'	9°00'	16°30'	5°45'	9°00'	16°30'	21°00'	31°00'	58°00'
Pavement widening										See table 3-2 and figure 3-4								
Vertical alignment:																		
Grade[11]																		
Desirable maximum																		
Percent	3	3	4	3	3	4	4	5	6	4	5	6	5	6	7	6	6	7
Critical length, ft[12]	1,035	1,035	720	1,035	1,035	720	720	550	450	720	550	450	550	450	375	450	450	375
Absolute maximum for permanent installations																		
Percent	5	6	6	5	6	6	6	7	8	7	8	9	8	9	10	10	10	10
Critical length, ft[12]	1,000	660	450	1,000	660	450	875	575	500	850	550	275	900	600	400	450	325	225
Absolute maximum for temporary installations																		
Percent				6	7	8	6	7	8	8	9	10	10	11	12	12	12	12
Critical length, ft[12]				825	550	325	875	550	500	750	500	250	200	525	375	450	300	200
Minimum, percent					0.3									0.5				
Vertical curves[13]																		
K for determining safe length																		
Crest vertical curves	240	150	80	240	150	80	150	80	80	115	65	40	115	65	40	28	24	15
Sag vertical curves	140	100	70	140	100	70	100	70	70	85	60	45	85	60	45	35	26	18
Minimum length, ft	210	180	150	210	180	150	180	150	150	165	135	105	165	135	105	90	75	60

Notes: 10 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.

11 See paragraph 3-3.d.(3) for exception to this criteria.

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 3-3.d.(3) of this manual.

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

Table 1-1. (Concluded)

Design Controls and Elements	Class A Road* Four-Lane Road			Class B Road** Two-Lane Road			Class C Road** Two-Lane Road			Class D Road** Two-Lane Road			Class E Road** Two-Lane Road			Class F Road** Single-Lane Road		
	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous	Flat	Rolling	Moun-tainous
Design Controls:																		
Traffic composition:[1]																		
T = 0%																		
DHV[2]	≥900	≥900	≥900	720-899	720-899	720-899	450-719	450-719	450-719	150-449	150-449	150-449	10-149	10-149	10-149	Under 10	Under 10	Under 10
T = 10%																		
DHV[3]	≥820	≥690	≥530	650-819	550-689	420-529	410-649	340-549	270-419	140-409	115-339	90-269	9-139	8-114	6-89	Under 9	Under 8	Under 6
T = 20%																		
DHV[3]	≥750	≥560	≥380	600-749	450-559	300-379	380-599	280-449	190-299	130-379	95-279	60-189	8-129	6-94	4-59	Under 8	Under 6	Under 4
T = 30%																		
DHV[3]	≥700	≥480	≥310	550-699	380-479	230-309	340-549	240-379	165-229	115-339	85-239	50-164	7-114	5-84	3-49	Under 7	Under 5	Under 3
Design speed, mph	70	60	50	70	60	50	60	50	50	55	45	35	55	45	35	30	25	20
Average running speed, mph	49	45	40	49	45	40	45	40	40	43	37	30	43	37	30	27	23	19
Cross-Section Elements:																		
Pavements:																		
Minimum width of traffic lanes, ft[4]																		
With barrier curbs	12	12	12	12	12	12	12	11	11	10	10	10	10	10	10	10	9	8
Without barrier curbs	12	12	12	12	12	12	12	11	11	10	10	10	10	10	10	12	11	10
Minimum distance between barrier curbs, ft[5]	53	53	53	29	29	29	28	26	26	24	24	24	20	20	20	15	14	13
Desirable lateral clearance to obstructions, ft[6]	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Normal cross slope, in./ft					1/8 to 1/4						3/16 to 3/8					1/4 to 1/2		
Curbs:[7]																		
Types										See paragraph 3-3.c.(3) of this manual								
Offset for barrier curbs	2.5	2.5	2.5	2.5	2.5	2.5	2.0	2.0	2.0	2.0	2.0	2.0	0	0	0	2.5	2.5	2.5
Medians[8]										See figure 3-2								
Shoulders:[9]																		
Minimum width, shoulders on roads without barrier curbs, ft	10	10	8	10	8	8	10	8	8	8	6	4	6	6	4	4	4	4

(Continued)

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% 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 DHVs 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 3-3.c.(2) of this manual.
5 Distance shown is the minimum distance between face of curbs.
6 10 feet if curbs are provided; see note 7.
7 Generally, curbs will not be provided on roads in open areas. See paragraph 3-3.c.(3) of this manual for "policy" on provisions of curbs within open areas at military 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.
8 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.c.(5) of this manual.
9 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.
* The DHV is in vehicles per hour per lane for direction of heavier flow.
** The DHV is in total vehicles per hour for all lanes in both directions.

Table 1-2. Geometric design policies for classified streets within "built-up" areas of military installation

Design Controls and Elements	Class A Street Four-Lane Street		Class B Street Two-Lane Street		Class C Street Two-Lane Street		Class D Street Two-Lane Street		Class E Street Two-Lane Street		Class F Street Two-Lane Street	
	Flat	Rolling	Flat	Rolling	Flat	Rolling	Flat	Rolling	Flat	Rolling	Flat	Rolling
Cross-Section Elements (Continued):												
Medians[10]	See figure 3-2											
Shoulders:[11]												
Minimum width, shoulders on streets without barrier curbs, ft	10	10	10	8	10	8	8	8	8	6	8	8
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											
Guardrails, guideposts, and earth slopes	See figure 3-3											
Bridge clearance	See paragraph 3-3.c.(8) of this manual											
Design Elements:												
Sight distance:												
Minimum stopping sight distance, ft	475	350	350	275	350	275	275	200	275	200	275	200
Horizontal alignment:												
Horizontal curves												
Absolute maximum for normal crown section	0°15'	0°30'	0°30'	0°45'	0°30'	0°45'	0°45'	1°30'	0°45'	1°30'	0°45'	1°30'
Absolute maximum for superelevated section[12]	4°00'	5°30'	5°30'	9°15'	5°30'	9°15'	9°15'	17°15'	9°15'	17°15'	9°15'	17°15'
Pavement widening	See table 3-2 and figure 3-4											
Vertical alignment:												
Grade												
Desirable maximum												
Percent	3	3	3	3	3	3	4	4	5	6	6	7
Critical length, ft[13]	800	600	900	550	900	550	750	475	400	200	700	450
Absolute maximum for permanent installations												
Percent	4	5	4	5	5	6	6	7	7	8	10	10
Critical length, ft[13]	900	600	675	200	600	300	500	200	450	175	400	250
Absolute maximum for temporary installations												
Percent			4	6	6	7	7	8	8	9	12	12
Critical length, ft[13]			500	275	500	275	450	200	200	150	600	200
Minimum, percent	0.3						0.5					
Vertical curves[14]												
K for determining safe length												
Crest vertical curves	150	80	80	50	80	50	50	28	50	28	50	28
Sag vertical curves	100	70	70	50	70	50	50	35	50	35	50	35
Minimum length, ft	180	150	150	120	150	120	120	90	120	90	120	90

Notes: 10 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.c.(5) of this manual. Generally, medians are provided with barrier curbs in built-up areas.

11 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.

12 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.

13 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 3-3.d.(3) of this manual.

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

Table 1-2. (Concluded)

by the letter "T," include all installation roads and streets which provide access from other roads and streets to individual units of facilities of a functional area.

(4) *Patrol roads.* Patrol roads, designated by the letters "PR," include all installation roads which are planned and designed for use in surveillance or in patrolling areas for security purposes. They will generally be designed for low volumes of light traffic.

(5) *Special considerations.* The above highways and roads may be required to accommodate overweight and oversize vehicles such as the Minuteman Transporter-Erector. Alignment, grades, and clearances will be adjusted, as required, to permit this traffic.

d. Types of open storage areas. Open storage areas are divided into two types according to anticipated use, as follows:

(1) *Vehicular.* A vehicular open storage area is an uncovered area planned and designed for the servicing, parking, or storing of passenger cars, trucks, tanks, or other wheeled vehicles at military installations. Various kinds of vehicular open storage areas are required by different services, as follows:

(a) Nonorganizational parking areas. Designated areas planned and designed for mass parking of privately owned visitors' vehicles, civilian employees, and attached personnel at community centers, administration buildings, hospitals, industrial buildings, barracks, quarters, housing areas, and other areas of public assembly.

(b) Organizational motor parks and motor pools. Designated areas designed and planned to provide control, security, and work space for maintenance and storage of organizational and administrative vehicles.

(c) Refueling vehicle area (Air Force). An area planned and designed for continuous operation of loaded refueling units.

(d) Post, base, and installation engineer areas. Designated areas planned and designed to provide adequate space for reception, classification, repair, and storage of vehicles and materials required for the maintenance and upkeep of buildings, grounds, and utility systems within a military installation.

(2) *Materiel.* A materiel open storage area is an uncovered area planned and designed for the storage of nonvehicular materiel and equipment at military installations.

e. Highway cross-section terms.

(1) *Roadway.* The portion of a highway, including shoulders, for vehicular use.

(2) *Roadbed.* The graded portion of a 1-6 highway usually considered as the area between the intersections of top and side slopes upon which the base course, surface course, shoulders, and median are constructed.

(3) *Median.* A directional separator located between two roadways carrying traffic in opposite directions.

(4) *Shoulder.* That portion of the roadway contiguous with the pavement for accommodation of stopped vehicles.

(5) *Curb.* A vertical or sloping member along the edge of a pavement or shoulder forming part of a gutter, strengthening or protecting the edge, and clearly defining the edge to vehicle operators.

(6) *Traffic lane.* That portion of the roadway for the movement of a single line of vehicles.

(7) *Parking lane.* An auxiliary lane primarily for the parking of vehicles.

f. Vehicle types.

(1) Passenger car, truck, light-delivery truck, bus, and truck combinations are as defined by AASHTO.

(2) *Half-track.* These self-propelled tactical vehicles designed for the transportation of personnel and materiel off highways are mounted on a combination of wheels and tracks. These are vehicles such as the M2A1, M16, M3, etc.

(3) *Full-track.* These self-propelled tactical vehicles designed for the transportation of personnel and materiel off highways are mounted on full tracks. These are vehicles such as tanks (M60, M1), carriers (M113), gun and howitzer carriages, etc.

(4) Special vehicles are to be described by using service.

g. Traffic terms.

(1) *Traffic composition.* The symbol "T," with percentage limitations, represents the proportion of the total traffic that is composed of buses, trucks, tanks, etc. The remainder of traffic is composed of light-delivery trucks and passenger cars.

(2) *Traffic volume.*

(a) Average daily traffic (ADT). The average 24-hour volume is the total volume during a stated period divided by the number of days in that period. Unless otherwise stated, the period is a year.

(b) Design hourly-volume (DHV). This is a volume determined for use in design representing traffic expected to use a facility during an hour. The daily peak hour (or the average daily peak hour over a period of days) should be used as the DHV. The DHV is one of the most important parameters for design, as it is the

basis for selection of other parameters which will determine the operating level of service for the completed facility.

(3) *Speed.*

(a) Design speed. This is a speed determined for design and correlation of the physical features of a highway. It is the maximum safe speed that can be maintained over a specified section of highway when the design features of the highway govern.

(b) Running speed. The running speed over a specific section of a highway is the distance divided by the running time. The average for all traffic, or component thereof, is the summation of distances divided by the summation of running times.

(4) *Capacity.* This is the maximum number of vehicles which can reasonably be expected to pass through a given section of a lane or roadway in one direction (or in both directions for a two- or three-lane highway) during a given time period under prevailing roadway and traffic conditions. Capacity is usually an hourly volume.

h. Sight distance.

(1) *Stopping sight distance.* This is the distance required by a driver of a vehicle, traveling at a given-speed, to bring his vehicle to a stop after an object on the roadway becomes visible.

(2) *Passing sight distance.* This is the maximum sight distance that will enable the driver of one vehicle to pass another vehicle safely and comfortably without interfering with the speed of an oncoming vehicle traveling at the design speed which appears after the overtaking maneuver is started.

i. Land-use terms.

(1) *Built-up areas.* Built-up areas are those within the site limits of a military installation which contains an aggregation of buildings, reasonably closely spaced, and arranged for housing, warehousing, and storage plant or depot purposes. In the highway system serving built-up areas, intersections of streets occur at intervals $^1/_4$ mile or less apart.

(2) *Open areas.* Open areas are all areas within the site limits of a military installation but outside its built-up areas. Open areas are typically designated for training, maneuver, ammunition storage, or other incidental purposes.

j. Types of structures.

(1) *Bridge.* This is a structure which spans a waterway or other opening under a highway.

(2) *Culvert.* Any structure not classified as a bridge which provides a waterway or other opening under a highway is a culvert.

k. Ideal conditions. Ideal conditions for two lane and multi-lane roads occur when no restrictive geometric, traffic, or environmental conditions are present, specifically:

(1) Design speed greater than or equal to 60 mph.

(2) Lane widths greater than or equal to 12 feet.

(3) Clear shoulders wider than or equal to 6 feet.

(4) No "no passing zones" on the highway.

(5) All passenger cars in the traffic stream.

(6) A 50/50 directional split of traffic.

(7) No impediments to through traffic due to traffic control or turning vehicles.

(8) *Level terrain.*

1-3. References. Appendix A contains a list of references used in this document.

CHAPTER 2
GENERAL PROVISIONS

2-1. Access highways. Provisions for permanent access highways and readjustment of the adjacent public highway system to serve military installations are covered in AR 55-80 (AFR 75-88). Since access roads or streets are seldom within the site limits of a military installation, their design and construction are normally the responsibility of the state, county, or other public authorities.

2-2. Installation highways.

a. Design criteria. Design criteria for roads and streets within military installations are presented herein and in TM 5-822-5/AFM 88-7, chapter 3, TM 5-822-6/AFM 88-7, chapter 1.

b. Planning. The planning of the road system is an integral part of installation master planning prescribed by TM 5-803-1, AR 210-20, AFM 86-4, and AFM 86-6. 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 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. Using the traffic studies outlined in Military Traffic Management Command Pamphlet No. 55-8 to determine traffic requirements, the geometric design of highway facilities will then provide for the safest, smoothest, and most convenient traffic movement-consistent with topographical conditions and economical construction. Existing roads and streets at military 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, alignment (horizontal and vertical), and passing sight distance. Values for these elements should be essentially equal to or greater than the minimum requirements for classification assigned.

2-3. Basis of design for roads, streets, and storage areas.

a. Geometric design. Geometric design criteria for roads, streets, walks, and open storage areas are presented in paragraphs 3-1 through 3-5. The following are the pertinent design controls:

(1) Topographic and physical features.
(2) Vehicle characteristics and dimensions.
(3) Traffic volume and composition.
(4) Capacity.
(5) Speed.
(6) Space allotments.
(7) Safety.

b. Structural design. Structural design criteria for flexible and rigid pavements for roads, streets, walks, and open storage areas are presented in TM 5-822-5/AFM 88-7, chapter 3, TM 5-822-6/AFM 88-7, chapter 1.

2-4. Traffic. The projected volume and anticipated composition of the traffic determine the geometric requirements for roads, streets, walks, and open storage areas. Type, volume, character, frequency, and composition of traffic at military installations are related to size, type, and mission of the installation. The type, size, and mission of the installation provide information as to its functional requirements indicating character and size of vehicles. Types of vehicles, type 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 sufficiently broad for the classification of all roads and streets within a military installation regardless of type and mission. A classification that reflects the character of traffic is based upon the characteristics and dimensions of existing civilian and military vehicles. The characteristics and dimensions of military vehicles are given in TM 9-500. Military vehicles include not only wheeled vehicles but also combined wheel and tracked vehicles. It is essential that a thorough analysis be made of all available data relative to anticipated traffic prior to selection of the type of design to use on a particular project. All traffic analyses will be made in accordance with methods presented in Military Traffic Management Command Pamphlet No. 55-8.

2-5. Anticipated life expectancy. In selection of roadway types, consideration should be given to the life expectancy of the installation served. Life expectancy of highways within permanent and established installations should be based on 25-year occupancy with normal maintenance. Temporary-type projects should use less costly structures and roadway types than those used at permanent installations.

CHAPTER 3
GEOMETRIC DESIGN

3-1. General. Geometric design deals with the dimensions of the visible features of a facility such as alignment, sight distances, widths, slopes, and grades. Geometric design policies are listed in tables 1-1 and 1-2 and discussed in subsequent paragraphs.

3-2. Definitions relative to geometric design. Definitions for specific terms not included in paragraph 1-2 relative to geometric design are presented by AASHTO (A Policy on Geometric Design of Highways and Streets) and the Transportation Research Board (Highway Capacity Manual).

3-3. Roads and streets.

a. Types.

(1) *Designations of types.* Highways may be grouped into various types on the basis of physical characteristics and ability to accommodate traffic. 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.

(2) *Single-lane roads.* Geometric design criteria for single-lane roads are shown in table 1-1 under "class F roads." Where shoulders are not sufficiently stable to permit all-weather use and the distance between intersections is greater than $^{1}/_{2}$ mile, turnouts shall 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. Access roads to unmanned facilities at Air Force installations will be classified as "class F roads" and shall be designed in accordance with the geometric design criteria presented for class F roads.

(3) *Two-lane roads and streets.* The bulk of the roads and streets at military installations are two-lane highways. These include class B, C, D, and E roads and class B, C, D, E, and F streets. Geometric design criteria are presented elsewhere in this manual.

(4) *Multilane (four traffic lanes or more,) highways.* A four-lane undivided highway is the narrowest highway on which each traffic lane is intended for use of traffic traveling in only one direction, and is not used by opposing traffic for passing. The design criteria presented herein for any highway are generally applicable to multilane highways also, except that passing sight distance is not required. The principal justification for construction of a multilane roadway is the capacity required to accommodate the anticipated traffic volumes. If traffic volumes require construction of multilane highways that are planned and designed for relatively high speeds, then opposing traffic should be separated by properly designed medians or concrete barriers. Of particular significance is the effect of wide medians in virtually eliminating head-on collisions. Rear-end collisions and other accidents related to left-hand turns are also reduced by use of wide medians to separate traffic. Divided highways designed to serve as expressways are seldom warranted within military reservations. This is due to the limited area of such installations and to the large expenditure of funds that must be made.

b. Design controls.

(1) *Topography and land use.* The location of a highway and its design elements are influenced to a considerable degree by the topography, physical features, excavation limits, and land use of the area traversed. These conditions are positive design controls, and information regarding them is essential. Tables 1-1 and 1-2 show appropriate design standards for roads and streets traversing flat, rolling, or mountainous terrain in built-up areas or open areas.

(2) *Vehicle characteristics.* Table 3-1 shows dimensions of design vehicles on which the geometric design criteria presented herein are based. Tracked vehicles used by the military services will fit into this group of design vehicles except for one dimension, i.e., width. Some of these vehicles are wider than 8.5 feet, which is the maximum width shown in table 3-1 for any of the design vehicles. The turning radii and dimensions of special vehicles will be obtained from the operating agency. 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 in 3-3*d*. (2). The selection of a design vehicle for use in design of grades is also discussed in 3-3*d*.(2)

Vehicle Type	Symbol	Wheel Base	Overhang Front	Overhang Rear	Overall Length	Overall Width	Height	Minimum Turning Radius Outside Front Wheel
		Dimensions in Feet						
Passenger	P	11	3	5	19	7.0	--	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*	4	6	50	8.5	13.5	40
Large	WB50	20 + 30 = 50*	3	2	55	8.5	13.5	45
Full trailer combination	WB60	9.7 + 20 + 9.4** + 20.9 = 60	2	3	65	8.5	13.5	45

Note: Dimensions of military vehicles are shown in TM 9-500, "Data Sheets for Ordnance-Type Material." 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 ensure that the largest vehicle expected to use the road or street can negotiate all turns, particularly if pavements are curbed.

* Length of tractor plus length of trailer.

** Distance between rear wheels of front trailer and front wheels of rear trailer.

Table 3-1. Design vehicle dimensions

(3) *Traffic.*

(a) Traffic studies. 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 ADT; the basic fundamental unit of measurement of traffic is DHV. Reasonable values for ADT and DHV can be determined through proper traffic studies and analyses of traffic data. Traffic studies will be made in accordance with methods presented in Military Traffic Management Command Pamphlet No. 55-8.

(b) 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 consequently impose a greater traffic load on highways than do passenger cars and light-delivery trucks. The average overall effect of these vehicles on traffic operation has been considered in formulating tables 1-1 and 1-2 as follows:

Number of Passenger Cars Replaced by One Truck, Bus, or Tracked Vehicle (All Classes)

Flat Terrain	*Rolling Terrain*	*Mountainous Terrain*
2.0	4.0	8.0

(c) Volume. Traffic volumes are expressed as 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, considerations must be given to the rush-hour periods. The DHV is to be used as a basis for geometric design. Limited studies made of traffic flows at military installations indicate that because of the high frequency with which peak hourly traffic occurs, the average daily peak (peak 15 minute period of traffic flow times 4) can be economically and efficiently used as the DHV. However, care must be taken in selection of the DHV. The DHV is the basis for selecting parameters which will determine the operating level of service for the completed facility. The DHV in tables 1-1 and 1-2 is shown as 15 and 12 percent, respectively, of the ADT. These are median values selected for military installations. If data collected show other conditions to exist, then the actual TM 5-822-2/AFM 88-7, Chap. 5 or predicted DHV should be used to determine the road or street class. The effective DHV (12 percent of ADT for streets and 15 percent of ADT for roads) adjusted for trucks, buses, and tracked vehicles in accordance with 3-3*b*.(3) *(b)* above corresponding to a given road or street classification can be summarized as follows:

Effective DHV (Equivalent Passenger Cars per Hour)

Class	*Road*	*Street*
A	≥900	≥1,200
B	720-899	1,000-1,199
C	450-719	750-999
D	150-449	250-749
E	10-149	25-249
F	<10	<25

DHV for various combinations of vehicular traffic is 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 diminishes for each highway class as the percentage of buses. trucks, and tracked vehicles in the traffic stream increases. The tables provide design data for traffic containing 0, 10, 20, and 30 percent buses, trucks, and tracked vehicles. Design data for other percentages of these vehicles may be determined by interpolation. The type and mission of the military installation will indicate the size and character of vehicles that will be used in installation operations. For example, traffic within storage depots will contain a larger percentage of trucks than traffic within a housing installation.

(4) *Capacity.*

(a) 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 alignment, 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.

(b) Capacity analysis (Highway Capacity Manual). A principal objective of capacity analysis is the estimation of the maximum amount of traffic that can be accommodated by a given facility. Capacity analysis would. however, be of limited utility if this were its only

focus. Traffic facilities generally operate poorly at or near capacity, and facilities are rarely designed or planned to operate in this range. Capacity analysis is also intended to estimate the maximum amount of traffic that can be accommodated by a facility while maintaining prescribed operational qualities.

(c) Capacity analysis is, therefore, a set of procedures used to estimate the traffic-carrying ability of facilities over a range of defined operational conditions. It provides tools for the analysis and improvement of existing facilities, and for the planning and design of future facilities.

(d) The definition of operational criteria is accomplished using levels of service. Ranges of operating conditions are defined for each type of facility, and are related to amounts of traffic that can be accommodated at each level.

(e) The following presents and defines the two principal concepts of this manual: capacity and level of service.

(5) *Capacity.* In general, the capacity of a facility is defined as the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions. The time period used in most capacity analysis is 15-minutes, which is considered to be the shortest interval during which stable flow exists.

(a) Capacity is defined for prevailing roadway, traffic, and control conditions, which should be reasonably uniform for any section of facility analyzed. Any change in the prevailing conditions will result in a change in the capacity of the facility. The definition of capacity assumes that good weather and pavement conditions exist. It is also important to note that capacity refers to a rate of vehicular or person flow during a specified period of interest, which is most often a peak 15-minute period. This recognizes the potential for substantial variations in flow during an hour and focuses analysis on intervals of maximum flow.

(b) Roadway conditions. Roadway conditions refer to the geometric characteristics of the street or highway, including the type of facility and its development environment, the number of lanes (by direction), lane and shoulder widths, lateral clearances, design speed, and horizontal and vertical alignments.

(c) Traffic conditions. Traffic conditions refer to the characteristics of the traffic stream using the facility. This is defined by the distribution of vehicle types in the traffic stream, the amount and distribution of traffic in available lanes of a facility and the directional distribution of traffic.

(d) Control conditions. Control conditions refer to the types and specific design of control devices and traffic regulations present on a given facility. The location, type, and timing of traffic signals are critical control conditions affecting capacity. Other important controls include STOP and-YIELD signs, lane use restrictions, turn restrictions, and similar measures.

(6) *Levels of service.* The concept of levels of service is defined as a qualitative measure describing operational conditions within a traffic stream and their perception by motorists and/ or passengers. A level-of-service definition generally describes these conditions in terms of such factors as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety.

(7) Six levels of service are defined for each type of facility for which analysis procedures are available. These definitions are general and conceptual in nature, and they apply primarily to uninterrupted flow. Levels of service for interrupted flow facilities vary widely in terms of both the user's perception of service quality and the operational variables used to describe them. They are given letter designations from A to F with level-of-service A representing the best operating conditions and level-of-service F the worst. In general, the various levels of service are defined as follows for uninterrupted flow facilities:

(a) Level-of-service A represents free flow. Individual users are virtually unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to maneuver within the traffic stream is extremely high. The general level of comfort and convenience provided to the motorist, passenger, or pedestrian is excellent.

(b) Level-of-service B is in the range of stable flow, but the presence of other users in the traffic stream begins to be noticeable. Freedom to select desired speeds is relatively unaffected, but there is a slight decline in the freedom to maneuver within the traffic stream from level-of-service A. The level of comfort and convenience provided is somewhat less than level-of-service A because the presence of others in the traffic stream begins to affect individual behavior.

(c) Level-of-service C is in the range of stable flow, but marks the beginning of the range of flow in which the operation of individual users becomes significantly affected by Interactions

with others in the traffic stream. The selection of speed is now affected by the presence of others, and maneuvering within the traffic stream requires substantial vigilance on the part of the user. The general level of comfort and convenience declines noticeably at this level.

(d) Level-of-service D represents high-density but stable flow. Speed and freedom to maneuver are severely restricted, and the driver or pedestrian experiences a generally poor level of comfort and convenience. Small increases in traffic flow will generally cause operational problems at this level.

(e) Level-of-service E represents operating conditions at or near the capacity level. All speeds are reduced to a low but relatively uniform value. Freedom to maneuver within the traffic stream is extremely difficult, and it is generally accomplished by forcing a vehicle or pedestrian to "give way" to accommodate such maneuvers. Comfort and convenience levels are extremely poor, and driver or pedestrian frustration is generally high. Operations at this level are usually unstable because small increases in flow or minor perturbations within the traffic stream will cause breakdowns.

(f) Level-of-service F is used to define forced or breakdown flow. This condition exists wherever the amount of traffic approaching a point exceeds the amount which can traverse the point. Queues form behind such locations. Operations within the queue are characterized by stop-and-go waves, and they are extremely unstable. Vehicles may progress at reasonable speeds for several hundred feet or more, then be required to stop in a cyclic fashion. Level-of-service F is used to describe the operating conditions within the queue as well as the point of the breakdown. It should be noted, however, that in many cases operating conditions of vehicles or pedestrians discharged from the queue may be quite good. Nevertheless, it is the point at which arrival flow exceeds discharge flow which causes the queue to form, and level-of-service F is an appropriate designation for such points.

(g) Capacity for uninterrupted flow. The Highway Capacity Manual presents methods for determining highway capacity for uninterrupted flow and methods by which this capacity is modified for interrupted flow. Therefore, it is necessary to determine the capacity for uninterrupted flow of both roads and streets. The capacity for interrupted flow should then be determined as described therein. The DHV shown in tables 1-1 and 1-2 is 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 miles per hour. Any factors which reduce or increase the average running speed will also reduce capacity. It is anticipated that there may be instances where the average running speed may be reduced substantially in which .case the capacity will also be reduced. In these instances the capacities (DHV) shown in tables 1-1 and 1-2 no longer apply. The capacities (DHV) shown in tables 1-1 and 1-2 for class A, B, and C roads and class A, B, C, 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 miles per hour.

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

(8) *Vehicle loads on Army and Air Force pavements.* Relations between load, load repetitions, and required pavement thickness developed from accelerated traffic tests of full-scale pavements have shown that, for any given vehicle, increasing the gross weight by as little as 10 percent can be equivalent to increasing the volume of traffic by as much as 300 to 400 percent. On this basis, the magnitude of vehicle loading must be considered more significant in the design of pavements than the number of load repetitions. For forklift trucks where the load is concentrated on a single axle, and for tracked vehicles where the load is evenly divided between the two tracks, the severity of the vehicle loading is a function of the gross weight of the vehicle and the number of load repetitions. The magnitude of the axle load is of greater importance than gross weight for most other multiaxle vehicles since axle spacings are generally large enough that there is little or no interaction between the wheel loads of one axle and the wheel loads of an adjacent axle. Thus, for multiaxle vehicles having uniform axle loads, the increased severity of loading produced by four- or five-axle trucks compared to two- or three-axle trucks is largely a fatigue effect resulting from a larger number of axle-load repetitions per vehicle operation.

(a) Pneumatic-tired vehicles. To aid in evaluating vehicular traffic for the purpose of pavement design. pneumatic-tired vehicles have been divided into the following three groups:

Group 1. Passenger cars, panel trucks, and pickup trucks
Group 2. Two-axle trucks
Group 3. Three-, four-, and five-axle trucks

The design weights for various pneumatic-tired vehicles have been based on average weights, as determined from Federal Highway Administration traffic surveys made on public highways, plus one-fourth of the difference between these average weights and the maximum allowable weights. For group 2 and group 3 vehicles, maximum allowable weights are based on single-axle and tandem-axle loadings not exceeding 18,000 and 32,000 pounds, respectively. Since traffic rarely will be composed of vehicles from a single group, pneumatic-tired vehicular traffic has been classified into five general categories based on the distribution of vehicles from each of the three groups listed above. These traffic categories are defined as follows:

Category I. Traffic composed primarily of passenger cars, panel and pickup trucks (group 1 vehicles) but containing not more than 1 percent two-axle trucks (group 2 vehicles).

Category II. Traffic composed primarily of passenger cars, panel and pickup trucks (group 1 vehicles), but containing as much as 10 percent two-axle trucks (group 2 vehicles). No trucks having three or more axles (group 3 vehicles) are permitted in this category.

Category III. Traffic containing as much as 15 percent trucks, but with not more than 1 percent of the total traffic composed of trucks having three or more axles (group 3 vehicles).

Category IV. Traffic containing as much as 25 percent trucks, but with not more. than 10 percent of the total traffic composed of trucks having three or more axles (group 3 vehicles).

Category IVA. Traffic containing more than 25 percent trucks.

(b) Tracked vehicles and forklift trucks. Tracked vehicles having gross weights not exceeding 15,000 pounds and forklift trucks having gross weights not exceeding 6,000 pounds may be treated as two-axle trucks (group 2 vehicles) and substituted for trucks of this type in the traffic categories defined in *(a)* above on a one-for-one basis. Tracked vehicles having gross weights exceeding 15.000 pounds but not 40.00 pounds and forklift trucks having gross weights exceeding 6,000 pounds but not 10,000 pounds may be treated as group 3 vehicles and substituted for trucks having three or more axles in the appropriate traffic categories on a one-for-one basis. Traffic composed of tracked vehicles exceeding 40,000-pound gross weight has been divided into the following three categories:

	Maximum Vehicle Gross Weight, pounds
Category	*Tracked Vehicles*
V	60,000
VI	90,000
VII	120,000

Forklift trucks exceeding 10,000-pound gross weight are treated in TM 5-809-12/AFM 88-3, chapter 15.

(9) Design index for Army and Air Force pavements. The design of pavements for Army and Air Force roads, streets, and similar areas is based on a "design index," which represents the combined effect of the loads defined by the traffic categories just described and the traffic volumes associated with each of the lettered classifications of roads or streets. This index extends from one through ten with an increase in numerical value indicative of an increase in pavement design requirements. Table 3-2 gives the appropriate design index for rigid pavements for combinations of the eight traffic categories based on distribution of traffic vehicle type and the six letter classifications based on the volume of traffic. For flexible pavements, the design index method is covered in TM 5-822-5/AFM 88-7, Chap. 3. For example, suppose an ADT of 2,000 vehicles composed primarily of passenger cars, panel trucks, and pickup trucks (group 1), but including 100 two-axle trucks (group 2) is anticipated for a road in flat terrain. First, from b.(3) above, the 100 trucks are equivalent to 200 passenger cars, giving an effective ADT of 2,100. The effective DHV is then 15 percent of 2,100, or 315, making this a class D facility. Second, the group 2 vehicles are 100/2,000 or 5 percent of the total of groups 1 and 2, making this category II traffic. Therefore, the appropriate design index from table 3-2 is 2.

(a) Tracked vehicles. Provision is made whereby the designer may determine pavement design requirements for tracked vehicles in combination with traffic by pneumatic-tired vehicles or for traffic by tracked vehicles only. Where both pneumatic-tired vehicles and tracked vehicles are to be considered, the proper letter classification of the road or street is determined according to the total volume of traffic from both types of vehicles. In most cases of traffic combining pneumatic-tired vehicles with tracked vehicles having gross weights in excess of 40,000 pounds, the determination of the appropriate traffic category will be governed by the tracked vehicle component of the traffic In table 3-2 the

Traffic Category	Pavement Design Index for Road or Street Classification					
	A	B	C	D	E	F
I	2	2	2	1	1	1
II	3	2	2	2	2	1
III	4	4	4	3	3	2
IV	5	5	5	4	4	3
IVA	6	6	6	5	5	4
V (60-kilopound (kip) track-laying vehicles):						
500/day	7	7	7	7	7	*
200/day	6	6	6	6	6	*
100/day	6	6	6	6	6	6
40/day	6	6	6	5	5	5
10/day	5	5	5	5	5	5
4/day	5	5	5	5	4	4
1/day	5	5	5	4	4	4
VI (90-kip track-laying vehicles):						
200/day	9	9	9	9	9	*
100/day	8	8	8	8	8	8
40/day	7	7	7	7	7	7
10/day	6	6	6	6	6	6
4/day	6	6	6	6	6	6
1/day	5	5	5	5	5	5
1/week	5	5	5	4	4	4
VII (120-kip track-laying vehicles):						
100/day	10	10	10	10	10	10
40/day	9	9	9	9	9	9
10/day	8	8	8	8	8	8
4/day	7	7	7	7	7	7
1/day	6	6	6	6	6	6
1/week	5	5	5	5	5	5

* Traffic limited to 100 vehicles per day.

Table 3-2. Rigid Pavement Design Index

traffic for categories V, VI, and VII has been divided further into various levels of frequency. If the tracked vehicle traffic is composed of vehicles from more than a single traffic category, it will be necessary for the designer to determine the anticipated frequency of traffic in each category in order to determine the appropriate design index. For example, 40 vehicles per day of category VI traffic require a greater pavement design index than does one vehicle per day of category VII traffic.

Thus, the designer cannot rely on maximum gross weight alone to determine rigid pavement design requirements for tracked vehicles. For vehicular parking areas, the design index should be determined from the column for class E roads or streets, again taking into account the relative traffic frequencies where there are tracked vehicles from more than a single traffic-category.

(b) Special-purpose vehicles. Information regarding pavement design requirements for special-purpose vehicles producing loadings significantly greater than those defined in this manual will be requested from Headquarters, Department of the Army (DAEN-ECE-G), Washington, DC 20314-1000; or Headquarters, Air Force Engineering and Services Center (AFESC/DEMP), Tyndall AFB, Fla. 32403-6001.

(10) *Speed.*

(a) Factors influencing geometric design. Vehicular speed varies according to the physical characteristics of the vehicle and highway as well as its roadsides, the weather, the presence of other vehicles, and speed limitations (either legal or because of control devices). 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.

(b) Design speed. The speed selected for design is the major control in design and correlation of the 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 policies presented herein are based on the design speeds shown under "Design Controls" in tables 1-1 and 1-2.

(c) Average running speed. The average running speeds on which the geometric design policies are based are shown under "Design Controls" in tables 1-1 and 1-2. These values were selected on the basis of information presented in AASHTO's A Policy on Geometric Design of Highways and Streets and the Highway Capacity Manual.

(11) *Safety.* Geometric features of a highway are designed for the safe, economic, and efficient passage of the(using traffic. Highway safety depends upon the proper arrangement of the physical features of the roadway, the characteristics of the vehicles using the highway, and the operators of the vehicles. Safety is related to lane width, conditions and width of shoulders, distance to lateral obstructions, maximum curvature, sight distance, and allowable speeds. The geometric design policies set forth in tables 1-1 and 1-2 have been established to ensure roadway conditions adequate to accommodate design volumes and permit operating speeds approaching the design speeds in a safe and efficient manner.

(12) Designations of design control factors. The major controls used in design of highways should be shown on the title sheet of construction plans for each project. The present ADT, the future average daily traffic (design ADT), the DHV, the percentage of trucks during the DHV (T), and the design speed (V), plus any other major design control factors should be shown for each project.

c. Cross-section elements.

(1) *Pavement.*

(a) 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 ability to drain, and the possible effect of pavement surface on driver behavior should be considered in geometric design. Use of the geometric and structural design criteria presented herein and in TM 5-822-5/AFM 88-7, chapter 3, and TM 5-822-6/AFM 88-7, chapter 1, will provide suitable pavements for classified roads and streets at military installations.

(b) 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, A Policy on Geometric Design of Highways and Streets. Cross slope on tangents and flat curves is shown in tables 1-1 and 1-2. Where two or more lanes are inclined in the same direction on class A roads and streets, each successive lane outward from the crown line shall 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 shall be increased $^{1}/_{16}$ inch per foot. Where pavements are designed with barrier curbs, it is recommended that a minimum cross slope of $^{3}/_{16}$ inch per foot be used on class A, B, and C roads and streets and that a minimum cross slope of $^{1}/_{4}$ inch per foot he used on class D, E. and F roads and streets.

(2) *Lane width.*

(a) Traffic lanes. Safety, driver comfort, and capacity are directly affected by lane width, and proper consideration must be given to each of these items. The width of a traffic lane is dependent upon the width and operational characteristics of vehicles, speed, composition, and volume of the traffic, and the location of barrier curbs. 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. Where class A, B, C, or D roads or streets are being planned to accommodate traffic of the composition "T = 20 percent" or greater, which includes vehicles greater in overall width than 8.5 feet, the traffic lanes of these roads or streets should be increased in accordance with the following formula:

$$W = w_t + (w_v \; 8.5) \qquad \text{(eq 3-1)}$$

where

W = width of widened traffic lane, feet

w_t = width of traffic lane shown in table 1-1 or 1-2, feet

w_v = average width of the 10 most representative excessive-width vehicles expected in the traffic, feet

The traffic lane of class E roads and streets planned to accommodate traffic of the composition "T = 30 percent" or greater should be widened as indicated above for class A, B, C, or D roads and streets. No adjustment will be made for excessive-width vehicles on class F roads or streets. Such adjustments are not economical for the low volumes associated with class F roads. Additional widening of traffic lanes is required on horizontal curves as discussed in 3-3*d*.(2) below.

(b) Parking lanes. It is the policy of the Department of Defense (DOD 4270.1-M) to provide off-street parking facilities at military installations in lieu of wider streets required for on-street parking. However, at many existing installations it may be necessary to provide on-street parking spaces in local areas by widening existing streets due to the lack of space for off-street parking facilities. Normally, such parking will not be provided on class A, B, or C existing streets, but in those instances where the provision of on-street parking on existing class B and C streets cannot be avoided, geometric design criteria for on-street parking lanes are given in table 1-2. Justification for all such on-street parking facilities will be furnished to Headquarters, Department of the Army (DAEN-ECE-G) Washington, DC 20314-1000, or the appropriate Air Force major command.

(3) *Curbs.*

(a) Policy. In built-up areas, curbs, combination curbs and gutters, and paved gutters with attendant underground storm drainage systems will be provided along streets and in open storage areas when 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. Inverts and sides of roadside ditches will be paved where necessary to control erosion. Criteria and standards for curbs and gutters for Department of the Air Force installations are specified in AFM 88-15, chapter 15.

(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 or 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. Standard details for each of these four types of curbs are shown in CE Standard Drawing No. 40-17-02. These details apply to both rigid and flexible pavements. The compacted subgrade. subbase, and base course layers should extend under the curb and for a distance equal to the base course thickness beyond the backface of the curb

(c) Location in regard to lane width includes type I, III, or IV (barrier) curbs. It is known that vehicles tend to veer away from lateral obstructions including barrier curbs. It has been found that lateral placement of the vehicle varies with slope of face, height, and length of barrier curbs. This tendency reduces the capacity of traffic lanes adjacent to barrier curbs. It is necessary therefore 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. Mountable curbs (type II) 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.

(4) *Shoulders.*

(a) Width. Usually the outside edge of the shoulder (intersection of shoulder and front slope plane) will be rounded. Rounding on shoulder edges improves the general appearance of the highway and reduces maintenance costs but causes a reduction in shoulder width. The steeper the front slope, the greater the reduction in width. Where front slopes are 4:1 or steeper, the overall shoulder width from table 1-1 or 1-2 will be increased in accordance with the tabulation below.

Front Slope in Cuts or on Fills	*Increase Minimum Shoulder Widths Shown in Tables 1-1 and 1-2 by Amount Shown, feet*
4:1	0.0
3:1	1.0
2:1	2.0
$1^1/_2$:1	3.0

On highways designed with mountable curbs, the width of curb and gutter sections is included in the minimum shoulder widths shown for roads and streets designed without barrier curbs in tables 1-1 and 1-2. Where guardrails or guideposts are required, the shoulders should be widened an additional 2 feet (see 3-3*c*.(6) below).

(b) 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.

(c) 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.

(5) *Medians.*

(a) 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.

(b) 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.

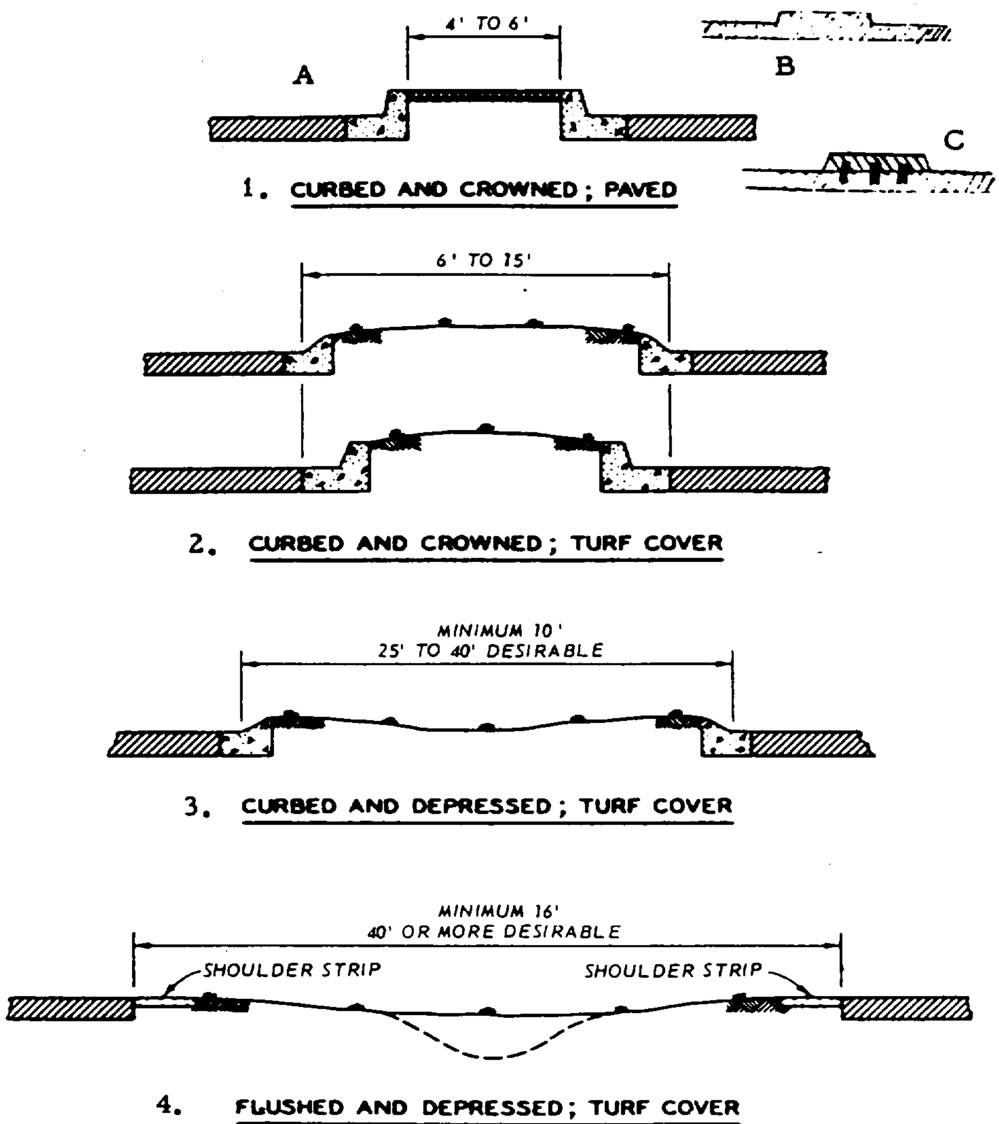
(c) Curbs. Special types of curbs for medians are-not required. Where they are designed with curbs, one of the standard-type curbs shown in CE Standard Drawing No. 40-17-02 will be used. Barrier curbs adjacent to medians will be offset the same distance shown for barrier curbs in tables 1-1 and 1-2. All design criteria relative to curbs presented herein are applicable to median curbs.

(d) Shoulders. Full-width shoulders are provided adjacent to the right (outside) lane of each pavement of divided highways to accommodate stopped vehicles. The shoulder adjacent to the left (inside) lane need not be wider than 4 feet. Shoulder strips are usually of contrasting color and are intended to increase safety and decrease maintenance costs. Where the pavements of divided highways are at different levels and separated by wide medians, the shoulder adjacent to the left lane is more important than in other types of divided highways from a safety viewpoint, and a shoulder of normal width should be provided adjacent to this lane. The minimum width for these median shoulders is 6 feet; 8-feet shoulders should be provided where feasible.

(e) Design for specific projects. Geometric design of medians for specific projects will be in accordance with AASHTO Highway Design and Operational Practice Related to Highway Safety and the Transportation Research Board Highway Capacity Manual.

(6) *Guardrails and guideposts.*

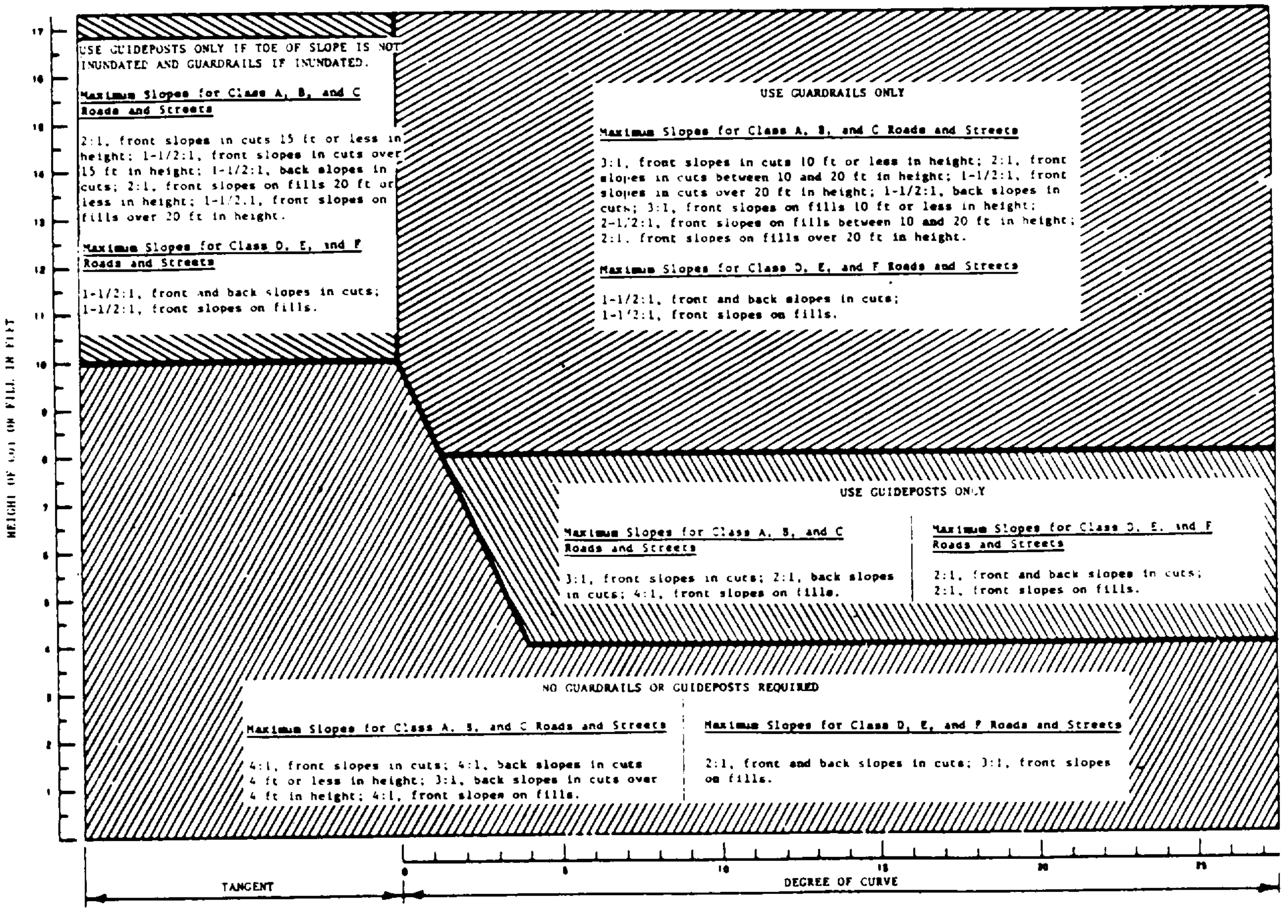
(a) Uses. For safety and guidance of traffic, guideposts should be provided at all locations along roadways where drivers may become confused, particularly at night, as to the direction of the roadway; along roadways subject to periodic flooding; along roadways where fog exists for long periods of time; and where driving off the roadway is prohibited for reasons



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.

Figure 3-1. Cross section 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 by the Office, Chief of Engineers.
2. Cuts in solid rock or loess should have vertical side walls; therefore, no back slope will be required in these materials.

Figure 3-2. Design policy for guardrails, guideposts, and earth slopes.

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.

(b) Design policy. Guardrails or guideposts are not normally required where the front side slopes are 4:1 or flatter. Design policy for determining where guardrails or guideposts are required is shown in 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 on fills, or between the toe and top of back slope in cuts.

(c) Location with respect of 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. Shoulder widths shown in tables 1-1 and 1-2 will be widened 2 feet to provide space for installation of guardrails or guideposts. Guardrail ends should be flared outward, covered with a mound of earth, protected with a crash cushion or breakaway terminal cable, or buried on the traffic approach end. Guardrails and alignment of guideposts should be tapered in at narrow structures to meet curb lines. See the AASHTO Guide for Selecting, Locating and Designing Traffic Barriers for more information.

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

(7) *Earth slopes.* In determining degree of sides slopes for cut and fill sections, consideration must be given to stability, drainage,

maintenance, and erosion. Stability is required to maintain the integrity of the pavement structure, and a slope stability analysis should be conducted for cuts and fills greater than 15 feet. For lower cut and fill heights, erosion and maintenance. considerations control the degree of slope. In general, side slopes should be no steeper than three horizontal to one vertical or two horizontal to one vertical with a bench system. Additional guidance for selecting degrees of slope is also presented in figure 3-2.

(8) *Bridge clearance.* Requirements affecting highway safety are found in AASHTO publication, A Policy on Geometric Design of Highways and Streets.

(a) Horizontal at short bridges. The minimum horizontal distance between curbs on short bridges must 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.

(b) Horizontal at long bridges. Where a long bridge is required, the designer should furnish a sketch of the proposed bridge and the basis for geometric and structural design to Headquarters, Department of the Army (DAEN-ECE-G) Washington, DC 20314-1000, or the appropriate Air Force major command.

(c) Vertical. The minimum vertical clearance will be at least 14 feet over all traffic lanes, parking lanes, and shoulders. An additional 6 inches should be included to accommodate future resurfacing.

d. Design elements.

(1) Sight distance. The length of roadway visible ahead of a vehicle along a highway is termed "sight distance." Sufficient sight distance should be available to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. Discussions relative to sight distance requirements for highway design in general are presented in AASHTO publications.

(a) Stopping sight distance. The stopping sight distance is the distance traversed by a vehicle from the instant the driver sights an object requiring a stop to the instant the brakes are applied, plus the distance required to stop the vehicle once the brakes are applied. On single-lane roads the stopping sight distance must be adequate to permit approaching vehicles from either direction to stop. The sight distance at every point along roads or streets must in all cases be equal to or greater than the minimum stopping sight distance shown in tables 1-1 and 1-2. Horizontal curve sight distance on single lane roads will be critical and will be twice that required for a two or more lane highway.

(b) Passing sight distance. The passing sight distance is the longest distance in which a driver can see the top of an oncoming vehicle, and the length of highway that must be visibly free of oncoming vehicles in order that the driver of a vehicle traveling at design speed can overtake and pass a slower moving vehicle without hazard. 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 miles per hour less than design speed. It is desirable to provide safe passing sections as frequently as possible to provide each safe passing section with a sight distance at least equal to but preferably greater than the minimum passing sight distances shown in table 1-1. Sight distances and safe passing sections should be shown on all construction and improvement plans to aid in proper marking and sign placement. These distances should not be confused with other distances used as the warrants for placing no-passing zone pavement stripes on completed highways. Such values (e.g. section 3B-5 of the Manual or Uniform Traffic Control Devices) are substantially less than design distances and are the result of operating control requirements based on different assumptions from those for highway design.

(2) *Horizontal alignment.*

(a) General. Where changes in horizontal alignment are necessary, horizontal curves should be used to effect 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 (roads and streets). 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. Absolute maximum values for degree of curvature on streets in built-up areas are shown in table 1-2.

(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, degree of curvature, frequency, and amount of precipitation and type of area, i.e., built-up or open. Superelevation rates will be determined in accordance with AASHTO methods.

(d) Widening of roads and streets. 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 (see WB40, WB50, WB60) 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 high type alignment, 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 3-3. 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 tangent-spiral (TS), attain the maximum at the spiral-curve (SC), and diminishing from the maximum at the curve spiral (CS) to zero at the spiral-tangent (ST) 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) *Vertical alignment.*

(a) Grade. It is essential that proper consideration be given to selection of grades for use in design of roads and streets at military installations. Selection of design grades involves traffic volumes, composition of traffic, average running speed, capacity, vehicle characteristics, drainage, safety, appearance, access to adjacent property, and economics. It is generally agreed that design grades for roads and streets is primarily dependent on vehicle characteristics, rate and length of grade, drainage, and safety. Control grades for design of roads and streets are shown in table 1-1. The values shown were established in accordance with AASHTO grade design methods and as presented in the Transportation Research Board (TRB) Highway Capacity Manual. The objective in selecting maximum grades for use in design is to determine the length of a designated upgrade (critical length) upon which a particular vehicle (design vehicle) can operate safely without reducing its speed below a specified speed (generally 30 mph). The term "maximum grade" in itself has no significance unless length of grade and type vehicle are stated. In grade design, gradeability of the vehicle is the most important factor. For comparative purposes, gradeability may be expressed by the weight-power ratio of a vehicle. According to AASHTO, and confirmed for military vehicles, a loaded truck of 40,000pounds gross weight powered so that the weight-power ratio is about 400 (100 horsepower) is representative of the size and type of vehicle which should be used for control of grade design. The maximum grades recommended for use in design of roads and streets, shown in table 1-1, were selected on the basis of these values. Since capacity of a road or street is directly affected by reduction in speed, there must be restrictions on speed reduction if the capacities shown in tables 1-1 and 1-2 are to be used for design; therefore, the distance the design vehicle can travel up a designated grade before vehicle speed is reduced to a specified value must be determined. This distance is termed critical length of grade. Critical lengths for grades shown in tables 1-1 and 1-2 are extracted from AASHTO publications. It is emphasized that the capacities (DHV) shown in tables 1-1 and 1-2 no longer apply on roads or streets where the length of designated grades is in excess of the critical lengths. In instances where the length of grades is longer than the critical length, the designer has three alternatives: change location to reduce grades, reduce capacity, or provide climbing lanes for heavy vehicles. Where the average daily traffic varies from two or three vehicles to none, the geometric design should be in accordance with the criteria provided for class F roads. except that the maximum grade should be determined on the basis of capability of vehicles required to use these roads. For instance, if all

Degree of Curve	Widening, in feet, for 2-Lane Pavements on Curves for Width of Pavement on Tangent of: 24 feet						22 feet					20 feet			
	Design Speed, mph						Design Speed, mph					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.

Table 3-3. Calculated and design values for pavement widening on roads and streets within military installations two-lane pavements, one-way or two-way

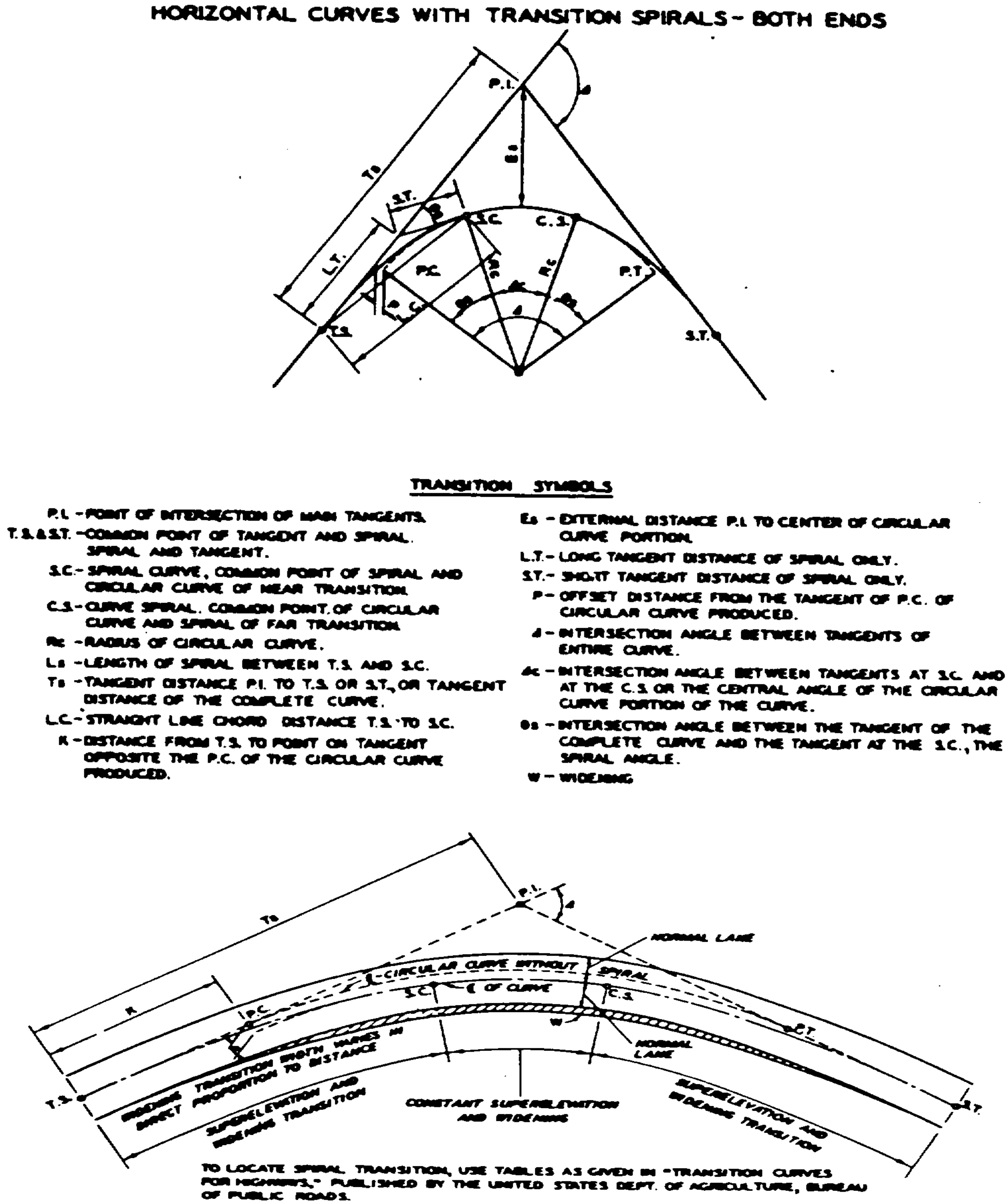


Figure 3-3. Method of layout of widening and superelevation of spiral lanes

vehicles required to furnish services are capable of operating on a continuous 15 percent grade, it would not be economical to provide a road with restricted length of 10 or 12 percent grade as required in table 1-1. In this instance the maximum grade should be 15 percent. Selection of minimum grade for use in design of roads and streets is dependent primarily on drainage requirements. Minimum grades are shown in tables 1-1 and 1-2. Designs for two-way, two-lane highways with climbing lanes are discussed in AASHTO publications. Justification for inclusion of climbing lanes in Army projects for two-way, two-lane highways will be furnished to Headquarters, Department of the Army, (DAEN-ECE-G) Washington, DC 20314-1000.

(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

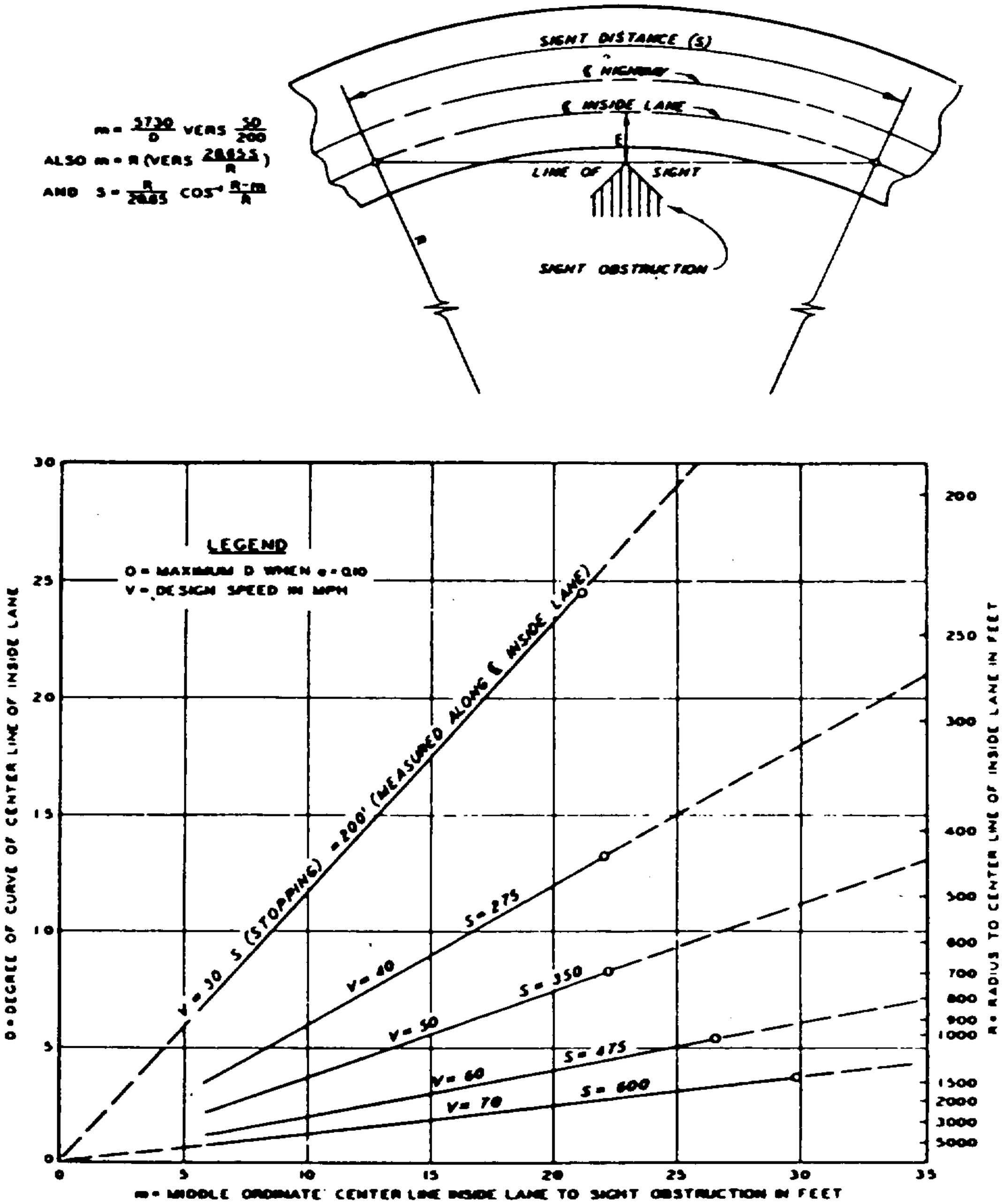


Figure 3-4. Stopping sight distance on horizontal curves and open road conditions.

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 economically feasible. The length of a vertical crest or sag curve required to provide minimum stopping distance is determined by the following formula:

$$L = KA \qquad \text{(eq 32)}$$

where

L = length of curve, feet

K = horizontal distance in feet required to effect a 1 percent change in gradient

A = algebraic difference of tangent grades, percent

Values for K for use in determining the length of vertical curves required for safety are shown in tables 1-1 and 1-2. The minimum length of vertical curves is also shown in tables 1-1 and 1-2. In each case the minimum length is equal to three times the design speed.

e. 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.

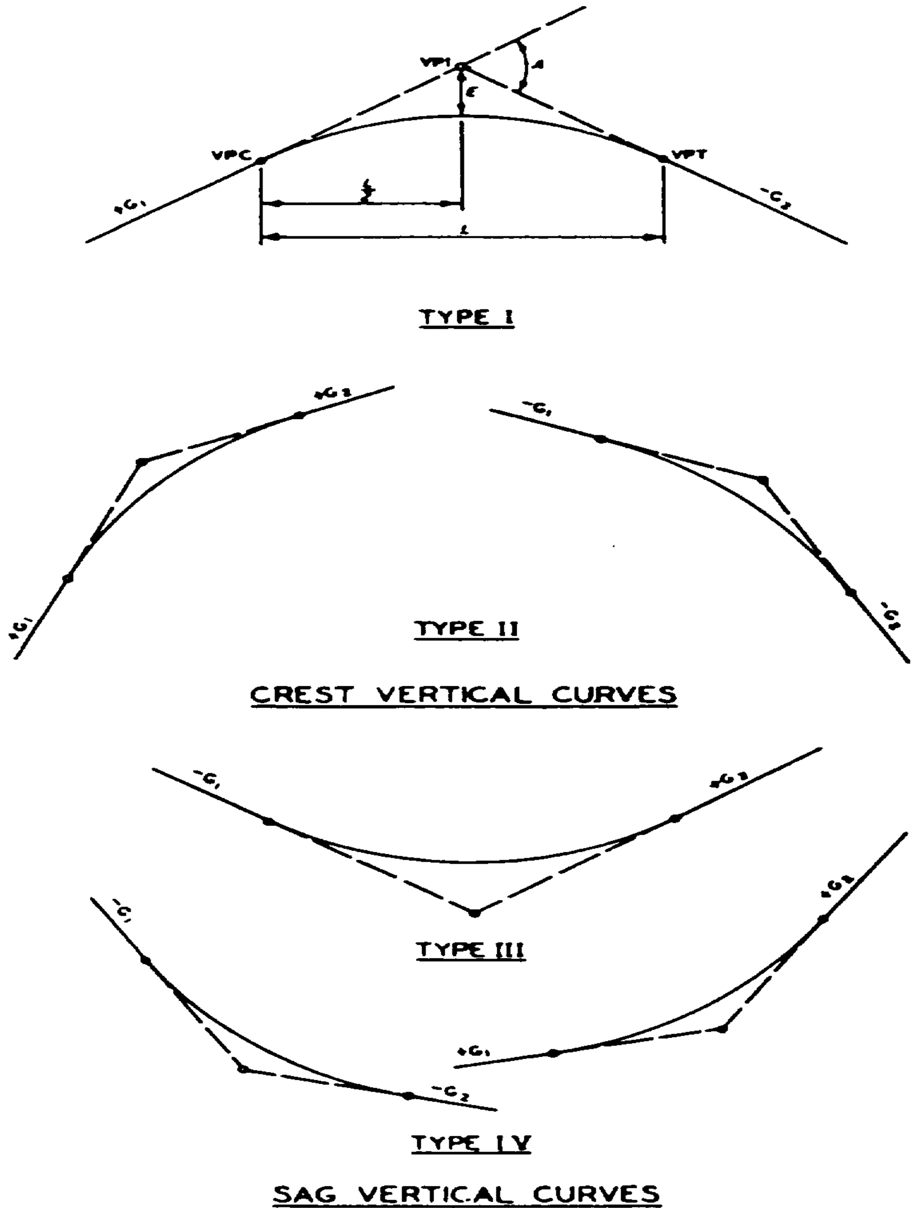


Figure 3-5. Types of vertical curves.

(1) *Roads.*

(a) 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 $2'/_{2}$:1.

(b) Superelevated section. Figure 3-6 shows the preferable superelevated cross sections for roads at military 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 parabolic curve between the shoulder and the front slope of the side ditch should be at least 4 feet long, at least the

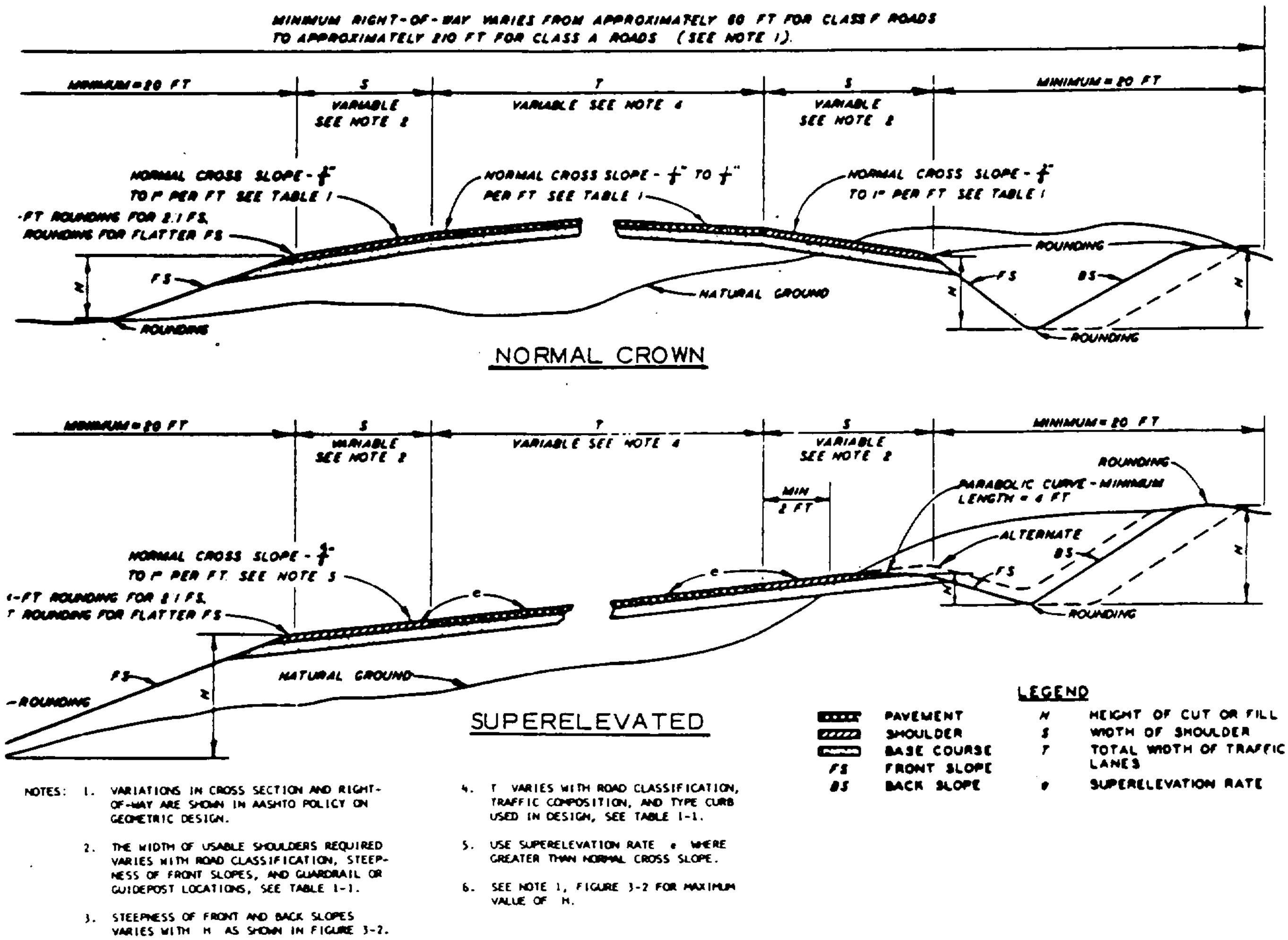


Figure 3-6. Typical road-type cross sections.

inside 2 feet of the shoulder should be held on the superelevated slope.

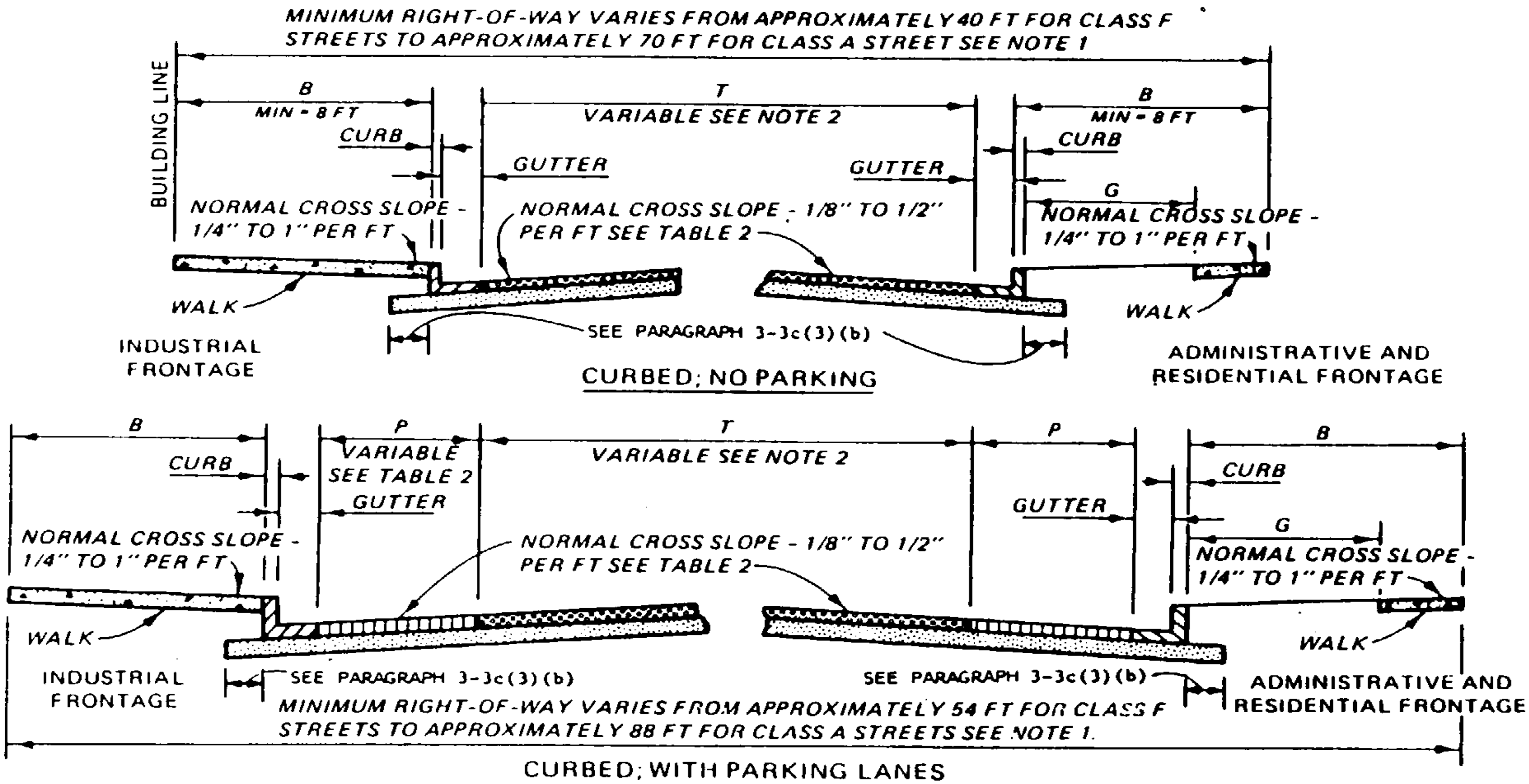
(2) *Streets.* Typical street-type cross sections with and without parking are shown in figure 3-7. Geometric design for the various cross-section elements shown is presented in table 1-2.

f. Intersections.

(1) *General.* Practically all highways within military 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.

(2) *Design criteria.* Geometric design criteria for intersections are presented in AASHTO publications and the TRB Highway Capacity Manual.

(3) Military 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 to use at a particular location on military installations should be 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.



NOTES
1. DIMENSIONS OF ELEMENTS OF CROSS SECTION NOT SHOWN ON THIS FIGURE ARE SHOWN IN TABLE 1-2.
2. T VARIES WITH STREET CLASSIFICATION, TRAFFIC COMPOSITION, AND TYPE CURB USED IN DESIGN.
3. AT AIR FORCE BASES OR STATIONS, WALKS WILL BE SET BACK FROM THE CURBS EXCEPT WHERE ON STREET PARKING IS PROVIDED.

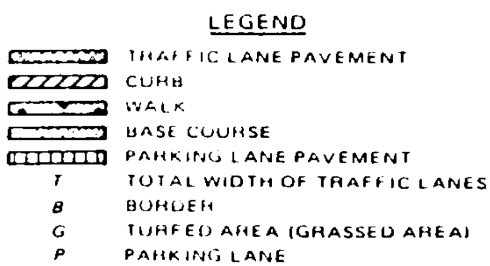


Figure 3-7. Typical street-type cross sections.

Area Designation Used in Highway Capacity Manual	*Equivalent Area at Military 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	See Page 137, TRB Highway Capacity Manual

(4) *Capacity of intersections.* Intersection of high traffic volumes is one prevailing traffic condition which will reduce average running speed and therefore reduce capacity. The capacity (DHV) shown in tables 1-1 and 1-2 is for free-flowing highways without intersections at grade or with few crossroads carrying minor traffic. These highways have no traffic control signals at intersections (plain unsignalized intersections); capacity is affected very little, and uninterrupted flow is assumed. With no traffic control, as cross- and turning-traffic volume increases, vehicles on both intersecting highways may have to slow down or come to a complete stop, reducing capacity. Relief from this situation may be obtained by designating one of the intersecting highways as the major one, and controlling traffic on the minor highway by stop signs. The traffic on the major highway can then be assumed to be uninterrupted. However, if traffic volume on the minor highway increases to the point that cross traffic cannot be properly controlled by stop signs, traffic control signals generally follow. At intersections with high-volume combinations, the cross-traffic interference causes a wavelike behavior of through traffic similar to traffic controlled by traffic signals. Thus, the capacity of intersections where uninterrupted flow cannot be assumed should be computed as if the intersections were operated under signal control irrespective of whether signal control is used. The AASHTO procedure is suggested as a guide in design of intersections. Certain traffic volume combinations will require wider traffic lanes on one or both intersecting highways to assure desirable operating conditions at signalized intersections. An analysis of various intersection traffic volumes assuming average conditions and signal control has been made to show what maximum traffic volume combinations may be used without requiring additional lane width. If the following volume combinations are exceeded, additional lane width in excess of that shown in tables 1-1 and 1-2 for classified roads and streets will be required.

AASHTO Suggested Design Hourly Volume Combinations Which Signal Control Should be Assumed in Geometric Design of Intersections Minimum DHV Two-way on:

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

Note: These volumes have no relation to warrant for signalization, nor do they indicate whether or not signalization should be used after the intersection is open to traffic

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 TRB 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 the Federal Highway Administration Manual on Uniform Traffic Control Devices for Streets and Highways.

(5) 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 designs 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 90degree turns. A larger radius should be used if any truck traffic is expected or turning speeds greater than 10 miles per hour 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. As shown in AASHTO urban literature, minimum curb radii vary with design vehicle, angle of turn, number of traffic lanes, whether parking is permitted, and traffic composition. Generally, the minimum curb radii to be used on intersection curves may be determined on the basis of the following information: Curb radii of 15 to 25 feet are adequate for P design vehicles and should be used on classes D, E, and F cross streets where practically no SU, WB40, WB50, and WB60 (truck) 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. Curb radii of 30 feet or more should be provided at all major highway intersections to accommodate an occasional truck in the traffic. 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.

g. *Miscellaneous.*

(1) *Signing.* Signs should conform with standards given in AASHTO's Manual of Uniform Traffic Control Devices and Standard Specifications for Structural Support for Highway Signs, Luminaries, and Traffic Signals.

(2) *Utilities.* Electric, communications, gas, water, and sewer lines will normally be located within the right-of-way of highways. In order to prevent utility maintenance from interfering with highway traffic, no underground utilities should be located beneath any part of the pavement, except where crossings are required. Where these underground utilities must cross beneath highways, they should be so designed and constructed as to minimize future repairs and consequent interference with traffic. Obstructions including signs and poles for overhead utilities shall be located outside the limits of usable shoulder on highways designed without barrier curbs. Where practicable, highways designed with barrier curbs should have the desirable lateral clearances to obstructions shown in tables 1-1 and 1-2, except that fire hydrant clearances shall be in accordance with TM 5-813-5 on Army installations. Generally, utility poles should not be located in medians on divided highways.

(3) *Railroad crossings.* The geometrics of a highway and a structure which entail the undercrossing or overcrossing of a railroad are substantially the same as for a highway grade separation without ramps. The geometrics of a highway at an at-grade crossing are discussed in American Railway Engineering Association (AREA) Manual for Railroad Engineering. The AREA recommends the practice which should be used at at-grade intersections of highways and railroads relative to signs, signals, gates, etc.

(4) *Pavement markings.* Marking should be provided on paved surfaces as a safety measure and to increase orderly traffic flow. Markings should be in accordance with the Manual on Uniform Traffic Control Devices for Streets and Highways.

3-4. Walks.

a. Need. At certain isolated locations in open areas, the need for walks may be as great as in built-up areas, especially in the vicinity of shopping centers, schools, industrial plants, and at other similar locations. Minimum walk requirements should be determined on the basis of need, irrespective of type of area, as a part of the master plan development.

b. Policy. Smooth, hard-surface walks should be provided to accommodate pedestrian traffic. Walks will be provided in accordance with American National Standard Institute (ANSI) Standard A117.1.

c. Geometric design. Safety and volume of pedestrian traffic are the primary controls for geometric design of walks. The traffic volume used for design should be the average of the maximum hour for each day for a year. However, since sufficient data are rarely available to determine this value, 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 military installations will be 3 feet for single family residences and at Air Force bases and stations for low volume traffic. 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 table 3-4. For instance, assuming that the design pedestrian traffic for walks at a particular shopping center is 1,700 pedestrians per hour, the width for these walks would be determined as follows:

$$W = 2\left(\frac{P_T - C_1}{C_1}\right) + 6 \qquad \text{(eq 3–3)}$$

where

W = width required by traffic

P_T = design traffic

C_1 = 750

Therefore

$$W = 2\,\frac{1{,}700 - 750}{750} + 6$$

$$W = 8.5 \text{ ft}$$

Walks in this shopping center would be 8 feet wide (nearest even-foot width).

Capacity of Walks in Pedestrians per Hour	Location of Walk	Minimum Width, Feet
Less than 10	Any location	3
10 to 100	Any location	4
100 to 750	Shopping centers	6
100 to 1,000	All other locations	6
Greater than 750	Shopping centers	$2\left(\frac{P_T - C_1}{C_1}\right) + 6$
Greater than 1,000	All other locations	$2\left(\frac{P_T - C_2}{C_2}\right) + 6$

Note: P_T = design pedestrian traffic volume in pedestrians per hour.

C_1 = 750 pedestrians per hour.

C_2 = 1,000 pedestrians per hour.

Table 3-4. Width of walks

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 ¼ inch per foot or more than ¼ inch per foot. The longitudinal grade should not be greater than about 15 percent. Steps should be avoided if possible but 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 the will be lighted by adjacent street or night lights. Requirements for steps are given in the DOD Construction Criteria Manual.

f. Location. It is desirable in the interest of safety to separate walk from curb line with a turfed area at least 5 feet wide as indicated by "G" in figure 3-7. In some instances, it may be necessary to place the walks adjacent to the curb to accommodate pedestrians in areas where curb parking is permitted or where material is loaded or unloaded at the curb. Walks should be located between and around the various facilities as required. Walks adjacent to roads should be located back of the ditch line or behind guideposts or guardrails. Where there is no ditch or fill of any consequence, the maximum area available should be allowed between the walk and the outside edge of the shoulder.

g. Warrant for walks adjacent to roads in open areas. The following tabulation can be used as a guide in determining the need for sidewalks adjacent to roads in open areas.

Pedestrian and Vehicle Volumes for Which the Construction of Sidewalks Might Be Considered

Vehicular Traffic, DHV	Pedestrians per day Suggested for Construction of Sidewalks *When Design Speed, mph, is*	
	30 to 50	*60 and 70*
Sidewalks, one side:		
30 to 100	150	100
More than 100	100	50
Sidewalks, both sides:*		
50 to 100	500	300
More than 100	300	200

*Lesser pedestrian traffic may justify two sidewalks to avoid considerable amount of cross traffic.

3-5. Open storage areas and parking.

a. General. This section deals with geometric d,-sign criteria for parking lots, motor pools, organizational motor parks, material storage areas, utility yards, and miscellaneous repair yards.

b. Location. General location and arrangement of open storage areas are shown for several types of Army installations in TM 5-840-2,TM 5-848-3, and TM 5-850-1.

c. Space allowances. Space allowances for Army open storage areas are given in TM 5-803-1 and TM 5-850-1. Space allowances for nonorganizational parking are given in DOD 4270.1M and AFM 86-2.

d. Standard drawings. Typical layout diagrams for various types of open storage areas required at Army and Air Force installations are shown in AFM 86-6, TM 5-403-1, TM 5-840 2, TM 5-848-3, and TM 5-850-1.

e. General requirements.

(1) Nonorganizational parking areas. Criteria on these areas are included in DOD 4270.1M. For Air Force requirements, see AFM 86-2.

(2) *Organizational motor parks.* These areas include all areas provided for storage, service, and repair of organizational and functional equipment assigned to the post or attached tactical units. The functional uses of these areas require that they be divided into areas for servicing and repair, and areas for storage or parking of vehicles. The former include all grease, wash, and inspection racks; fuel dispensing units; and similar miscellaneous facilities; as well as access drives to the various service facilities and the necessary outside wash areas. The storage area is used for parking or storing individual units of equipment. Maximum parking capacity can be obtained by requiring assigned vehicles to park as specified in (1) above for parking areas. The size of the service area is dependent upon the type and number of service facilities required.

(3) *Material storage areas.* Suitable areas for the reception, classification, handling, and storage of materials which can be placed in the open at little or no risk of damage from exposure to weather will be required at nearly all types of military installations. Material storage areas are provided at storage depots and at plant projects in accordance with authorized requirements. Typical layout diagrams showing relation between material storage areas and other facilities at Army installations are included in TM 5--840-2, TM 5-848-3, and TM 5-850-1.

(4) *Utility and miscellaneous repair yards.* The size and shape of these areas may vary considerably, and no general requirements for these areas are available. The size and shape should be based on actual needs and should be the minimum in cost consistent with functional requirements and anticipated life expectancy.

3-6. Residence drive. Driveways at residences shall extend from the street or alley pavement, or curb line to the garage, carport, or parking space. Driveways shall have a minimum width of 10 feet and shall flare out at the entrance. Minimum flare will be a 5-foot-radius curve connecting the line of the street curb-face and the driveway edge beyond the flare. Other flare configurations may be used, but the paved area represented by the minimum requirements indicated above must be provided. Curving driveways will require greater widths depending on the degree of curvature; driveways off narrow streets or alleys or those not perpendicular to the street will require greater entrance widths depending on the sharpness of turn required of entering vehicles. Maximum crown or cross-slope shall be 5 percent and minimum 1 percent.

3-7. Bridges and underpass roadways. Approval shall be obtained from appropriate Engineering Commands prior to construction of bridges, particularly major bridges over navigable waterways.

a. Widths. For roadway, shoulder, curb, and sidewalk requirements, see AASHTO A Policy on Geometric Design of Highways and Streets and Standard Specifications for Highway Bridges.

b. Railings. See AASHTO Standard Specifications for Highway Bridges. Use open-type railings over all water courses where the possibility of flooding exists.

c. Lighting. For type, intensities, etc., see AFM 88-15. For distance of lighting standards from roadway, see AASHTO A Policy on Geometric Design of Highways and Streets.

APPENDIX A
REFERENCES

Department of Defense

DOD 4270.1-M	Construction Criteria Manual
MTMC Pam. 55-8	Traffic Engineering Study Reference

Departments of the Army and the Air Force

AR 55-80 (AFR 75-88)	Highways for National Defense
AR 210-20	Master Planning for Permanent Army Installations
AFM 862	Standard Installations Facility Requirements
AFR 864	Base Comprehensive Planning
AFM 86-6	Air Base Master Planning Manual
AFM 88-15	Air Force Design Manual-Criteria and Standards for Air Force Construction
TM 5-803-1	Installation Master Planning Principles and Procedures
TM 5-813-5	Water Supply; Water Distribution Systems
TM 5-840-2	Storage Facilities; Storage Depots
TM 5-848-3	Ground Storage of Coal
TM 5-850-1	Engineering and Design of Military Ports
TM 9-500	Data Sheets for Ordnance-Type Materiel
TM 5-809-12/AFM 88-3, Chap. 15	Concrete Floor Slabs on Grade
TM 5-822-5/AFM 88-7, Chap. 3	Engineering and Design: Flexible Pavements for Roads, Streets, Walks, and Open Storage Areas
TM 5-822-6/AFM 88-7, Chap 1.	Rigid Pavements for Roads, Streets, Walks, and Open Storage Areas

Department of Transportation, Federal Highway Administration (FHA)

Manual on Uniform Traffic Control Devices for Streets and Highways*

Nongovernment References

American Association of State Highway and Transportation Officials (AASHTO), 341 National Press Building, Washington, DC

A Policy on Geometric Design of Highways and Streets (1984) Guide for Selecting, Locating and Designing Traffic Barriers (1977)

Highway Design and Operational Practices Related to Highway Safety (1974)

Standard Specifications for Highway Bridges (1973)

Standard Specifications for Structural Support for Highway Signs, Luminaries, and Traffic Signals (1975)

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Institute of Traffic Engineers, *Transportation and Traffic Engineering Handbook,* New Haven, CN, 1982.

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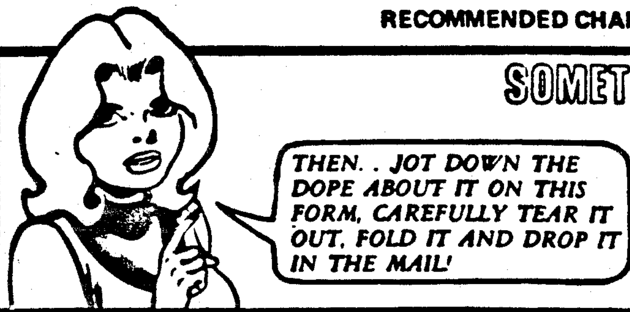

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