TABLE OF CONTENTS
PART III – MINIMUM DESIGN STANDARDS
Section 100

STREETS

SECTION	TITLE		PAGE
100.1	**GENERAL**		**100.1**
100.2	**REPORTS**		**100.1**
	100.2.1	Submittal Format	100.1
	100.2.2	Traffic Impact Analysis Report	100.1
	100.2.3	Pavement Design Report	100.2
	100.2.4	Pavement Evaluation Report	100.2
100.3	**STREET CHARACTERISTICS**		**100.2**
	100.3.1	Local	100.2
	100.3.2	Minor Collector	100.3
	100.3.3	Collector	100.3
	100.3.4	Major Collector	100.4
	100.3.5	Arterial Parkway	100.4
	100.3.6	Principal Arterial Parkway	100.4
100.4	**HORIZONTAL ALIGNMENT**		**100.5**
	100.4.1	Horizontal Curves	100.5
	100.4.2	Curb Return Radii	100.5
	100.4.3	Superelevation	100.6
	100.4.4	Stopping Sight Distance	100.6
	100.4.5	Small Deflection Angles	100.8
	100.4.6	Compound Curves	100.8
	100.4.7	Reversing Curves	100.8
	100.4.8	Broken-Back Curves	100.8
	100.4.9	Alignment at Bridges	100.8
	100.4.10	Coordination with Vertical Alignment	100.8
	100.4.11	Railroad Crossings	100.9
100.5	**VERTICAL ALIGNMENT**		**100.9**
	100.5.1	Permissible Roadway Grade	100.9
	100.5.2	Permissible Intersection Grades	100.10
	100.5.3	Changing Grades	100.10
	100.5.4	Vertical Curves	100.10
	100.5.5	Intersections	100.12
	100.5.6	Curb Returns	100.12
	100.5.7	Curb Return Profiles	100.13
	100.5.8	Connection with Existing Roadways	100.13
	100.5.9	Off-Site Design	100.14
100.6	**INTERSECTION AND DRIVEWAY SIGHT DISTANCES**		**100.14**
	100.6.1	General	100.14
	100.6.2	Intersection Sight Distance	100.14
100.7	**ROADWAY CROWN**		**100.19**
	100.7.1	Cross Slope	100.19

SECTION	TITLE	PAGE
100.8	SIDEWALKS, CURB AND GUTTERS, RAMPS, AND DRIVEWAYS	100.19
100.9	CUL-DE-SACS	100.20
100.10	AUXILIARY LANES	100.20
100.11	STREET LIGHTING	100.21
100.12	SIGNING AND STRIPING	100.21
100.13	UTILITIES	100.21
100.14	DRAINAGE	100.21
100.15	SUBGRADE INVESTIGATION FOR PAVEMENT DESIGN	100.22
100.16	PAVEMENT DESIGN CRITERIA	100.24
100.17	PAVEMENT DESIGN PROCEDURE	100.27

PART III - MINIMUM DESIGN STANDARDS
SECTION 100

STREETS

100.1 GENERAL

All curb, gutter, sidewalk and street design, rights-of-way and street widths shall conform to the minimum requirements of the City of Arvada Standard Specifications and Drawings for Design and Construction and the City Subdivision Regulations. Definition of streets shall be as defined therein. Care shall be taken to ensure continuity of grades, widths, etc., of proposed, existing and future installations. Private non-commercial streets and parking lots shall be built to these Standards, including curbs, gutters and sidewalks, unless otherwise approved by the Engineer. These Standards shall apply to all new streets within the City of Arvada and do not necessarily apply to all existing streets.

100.2 REPORTS

100.2.1 Submittal Format

All reports shall be bound in an 8-1/2" x 11" folder and shall include the seal and signature of the Professional Engineer registered in the State of Colorado who is responsible for the report contents.

100.2.2 Traffic Impact Analysis Report

A Traffic Impact Analysis (TIA) shall be required with applications for development review and approval when the trip generation during any peak hour is expected to exceed more than 100 trips during any one-hour peak or to exceed 250 trips per day, based on traffic generation estimates of the Institute of Transportation Engineers' Trip Generation Manual (or any successor publication). The City may also require a TIA for any of the following conditions:

A. Any project that proposes access to a street with a Level of Service (LOS) "D" or below;

B. Any application for rezoning;

C. Any case where the previous TIA for the property is more than two years old;

D. Any case where increased land use intensity will result in increased traffic generation; and

E. As may be required by the City Engineer or designee to address traffic issues that may be affected by the proposed project.

Traffic Impact Analysis reports shall be completed by a Professional Engineer licensed in the state of Colorado who has experience in completing TIAs.

100.2.3 Pavement Design Report

All roadway construction in the City of Arvada shall require a pavement design report. The report content shall be in accordance with Section 100.15 through 100.17 of these Standards and include a supporting geotechnical report.

100.2.4 Pavement Evaluation Report

After installation of the bituminous surface course, except for the final one and one-half inch (1-1/2") on residential streets, the developer may be required to furnish the City Engineer or designee with a copy of a report prepared by a Professional Engineer registered in the State of Colorado utilizing non-destructive deflection testing to assess and predict the performance of the pavement. This testing may be required if evidence exists that the pavement section may not meet the design specifications. The Professional Engineer shall have a past history and knowledge in performing these tests. Qualifications of Professional Engineers shall be submitted to the City Engineer or designee for approval before the start of work.

The pavement evaluation shall be performed in accordance with good engineering practices. The report shall generally embody the following testing and pavement evaluation techniques:

A. Environmental Study (Frost Cycle, Drainage, etc.).

B. Pavement Surface Elevation.

C. Soil Borings in Areas of High Deflections.

D. Pavement Deflection Analysis.

The report shall evaluate the existing condition of the base and binder course by performance of deflection tests at one-hundred-foot (100') spacings per traffic lane. Spacing will be staggered in each lane. The report shall determine whether or not the pavement section will meet a 20-year pavement life or greater.

If the pavement section is not projected to meet a life expectancy of 20 years or more, the report shall propose asphalt overlays in excess of the existing pavement section to bring the new pavement section to a 20-year life expectancy. The City Engineer or designee will evaluate the results of the report and inform the developer of the acceptable solution mentioned in the report.

100.3 STREET CHARACTERISTICS

100.3.1 Local (See ST-3 for Cross Sections and Additional Information)

A local street is a general term denoting a roadway designed or operating with the following characteristics:

A. Design Speed. 30 miles per hour with a generally posted speed limit of 25 – 30 miles per hour.

B. Traffic Volumes. Generally less than 1,000 vehicles per day.

C. Function / Access. Designed for ease of direct access to adjacent parcels of land. Residential properties may front on local streets.

D. Traffic Control. Regulation of traffic is accomplishes through the use of stop signs, yield signs, or right-of-way rules for uncontrolled intersections as in accordance with the current edition of the Manual on Uniform Traffic Control Devices (MUTCD).

E. Cul-De-Sacs. In accordance with Section 100.9 of these Standards.

100.3.2 Minor Collector (See ST-2 for Cross Sections and Additional Information)

A minor collector is a general term denoting a roadway designed or operating with the following characteristics:

A. Design Speed. Between 35 and 40 miles per hour with a generally posted speed limit of 30 - 35 miles per hour.

B. Traffic Volumes. Generally less than 3,000 vehicles per day.

C. Function / Access. Minor collectors are designed to handle traffic volumes loading from and onto private drives, locals, other collectors, and arterial roadways. Minor collectors collect and distribute traffic between arterial streets and local streets and serve as the main connectors within communities and generally serve intra-city travel. Residential properties may front on and have direct access to minor collector streets.

D. Traffic Control. Regulation of traffic is accomplished through the use of stop signs, traffic signals and channelization in accordance with the current edition of the Manual on Uniform Traffic Control Devices (MUTCD).

100.3.3 Collector (See ST-2 for Cross Sections and Additional Information)

A collector is a general term denoting a roadway designed or operating with the following characteristics:

A. Design Speed. Between 35 and 45 miles per hour with a generally posted speed limit between 30 and 40 miles per hour.

B. Traffic Volumes. Generally less than 8,000 vehicles per day.

C. Function / Access. Major collectors are designed to handle traffic volumes loading from and onto local, other collector, and arterial roadways. Major collector streets collect and distribute traffic between arterial and local streets and serve as main connectors within and between communities. Left turn lanes may be required at intersections and access points by the City Engineer or designee. Access is generally limited and may be restricted. Single family residential frontage is discouraged and back-out drives are prohibited except in unique circumstances.

D. Traffic Control. Regulation of traffic accomplished through the use of signs, traffic signals and channelization in accordance with the current edition of the Manual on Uniform Traffic Control Devices (MUTCD).

100.3.4 Major Collector (See ST-2 for cross sections and additional information)

A major collector is a general term denoting a roadway designed or operating with the following characteristics:

A. Design Speed. Between 40 and 45 miles per hour with a generally posted speed limit of 40 miles per hour.

B. Traffic Volumes. Generally less than 15,000 vehicles per day.

C. Function/Access.. Major collectors are designed to handle traffic volumes loading from and onto local, other collector, and arterial roadways. Major collector streets collect and distribute traffic between arterial and local streets and serve as main connectors within and between communities. Left turn lanes may be required at intersections and access points by the City Engineer or designee. Access is generally limited and may be restricted. Single family residential frontage is discouraged and back-out drives are prohibited except in unique circumstances.

D. Traffic Control. Regulation of traffic accomplished through the use of signs, traffic signals and channelization in accordance with the current edition of the Manual on Uniform Traffic Control Devices (MUTCD).

100.3.5 Arterial Parkway (4-Lane) (See ST-1 for Cross Section and Additional Information)

An arterial parkway street is a general term denoting a roadway designated or operating with the following characteristics:

A. Design Speed. Between 40 and 50 miles per hour with a generally posted speed limit between 40 and 45 miles per hour.

B. Traffic Volumes. Generally less than 30,000 vehicles per day when the land that the arterial serves is fully developed.

C. Function / Access. Arterial parkway streets are designed to handle traffic loading from other arterials, collector streets and occasionally from local streets. They are intended to serve regional and intra-city, multi-modal travel. Direct access from residential properties is prohibited. Direct access from all other land uses is also prohibited but may be permitted if a traffic impact analysis is submitted demonstrating that the access is necessary to preserve or improve the current level of service on the arterial or nearby intersections and can function safely. Access movements may be restricted or prohibited.

D. Traffic Control. Regulation of traffic is accomplished by signs, traffic signals and channelization in accordance with the current edition of the Manual on Uniform Traffic Control Devices (MUTCD).

100.3.6 Principal Arterial Parkway (4-Lane with provision for 6 lane) (See ST-1 for Cross Section and Additional Information)

A principal arterial parkway street is a general term denoting a roadway designated or operating with the following characteristics:

A. Design Speed. Between 45 and 55 miles per hour with a generally posted speed limit between 45 and 50 miles per hour.

B. Traffic Volumes. Generally greater than 30,000 vehicles per day expected minimum traffic volume when the land that the arterial serves is fully developed.

C. Function / Access**.** Principal arterial parkway streets are designed to handle traffic loading from other arterials, collector streets and occasionally from local streets. They are intended to serve regional and intra-city, multi-modal travel. Direct access from residential properties is prohibited. Direct access from all other land uses is also prohibited but may be permitted if a traffic impact analysis is submitted demonstrating that the access is necessary to preserve or improve the current level of service on the arterial or nearby intersections and can function safely. Access movements may be restricted or prohibited.

D. Traffic Control. Regulation of traffic accomplished by signs, traffic signals and channelization as per the current edition of the Manual on Uniform Traffic Control Devices (MUTCD).

100.4 HORIZONTAL ALIGNMENT

100.4.1 Horizontal Curves

The minimum horizontal curves for roadway alignment shall be in accordance with the Table below. For unique or unusual circumstances AASHTO design guidelines should be considered as approved by the City Engineer or designee.

TABLE 100.1

HORIZONTAL CURVES

	Principal Arterial Parkway	Minor Arterial / Arterial Parkway	Major Collector	Minor Collector	Local
Design Speed (MPH)	45-55	40-50	35-45	30-35	30
Minimum Curve Radius (ft.)	700	600	350	300	150

100.4.2 Curb Return Radii

Minimum return radii shall be as shown in the Table below.

TABLE 100.2

Curb Return Radii (Measured Along Flowline)			
	Intersecting Streets		
Through Street	Arterial	Collector	Local
Arterial	30 ft.	30 Ft	30 ft.
Collector	30 ft.	25 Ft	25 ft.
Local	30 ft.	25 Ft	18 ft.

100.4.3 Superelevation

Superelevation is generally recommended for curves on all arterial roadways and major collector roadways in the City. All roadway designs using superelevation are subject to review and approval by the City Engineer or designee. Recommendations of the AASHTO "A Policy on Geometric Design of Highways and Streets", latest edition (Green Book) should be consulted in the design of superelevation.

Superelevation shall not be used on local or minor collector roads.

100.4.4 Stopping Sight Distance.

Stopping sight distance is calculated in accordance with the 2011 6th Edition of the AASHTO "Green Book" Section 3.2.2. Stopping sight distance is the sum of two distances:

1) The distance traversed by the vehicle from the instant the driver sights an object necessitating a stop to the instant the brakes are applied, and
(AASHTO, p. 3-2)

2) The distance needed to stop the vehicle from the instant brake application begins (AASHTO, p. 3-2)

For passenger vehicles, stopping sight distance is measured from the driver's eyes, which is assumed to be 3.50 feet above the road surface, to an object with a height 2.0 feet above the road surface (AASHTO, p. 3-14 3-15).

Table 100.3 represents the stopping sight distance required on level roadways.

Stopping sight distance can be effected by the grade of the road. Upgrades require a shorter stopping sight distance while downgrades require a longer stopping sight distance (AASHTO, p. 3-5). Table 100.4 shows the stopping sight distance for various grades.

Stopping sight distance on horizontal curves is calculated in accordance with the 2011 6th Edition of the AASHTO "Green Book" Section 3.3.12. In the design of a horizontal curve, the sight line is a chord of the curve, and the stopping sight distance is measured along the centerline of the inside lane around the curve like what is shown in Standard Drawing ST-18 (AASHTO, p 3-106). For passenger vehicles, it is assumed that the driver's eyes are 3.50 feet above the center of the inside lane and the object height is 2.0 feet above the road surface (AASHTO, p. 3-109). Possible sight obstructions include walls, cut slopes, bridge abutments, and the side or corners of buildings. The stopping sight distance design procedure shall assume that a 6'-0" fence (as measured from actual finished grade) exists at all property lines except in the sight distance triangles required at all intersections. Figure 3-22b in Section 3.3.12 of the AASHTO "Green Book" shows the horizontal offsets (HSO) needed for clear sight that satisfies stopping sight distance criteria shown in Table 100.3 for various horizontal curve radii (AASHTO, p. 3-106).

TABLE 100.3 – Stopping Site Distance on Level Roadways

Design Speed (mph)	Brake Reaction Distance (ft)	Braking Distance on Level (ft)	Stopping Sight Distance (S)	
			Calculated (ft)	Design (ft)
15	55.1	21.6	76.7	80
20	73.5	38.4	111.9	115
25	91.9	60.0	151.9	155
30	110.3	86.4	196.7	200
35	128.6	117.6	246.2	250
40	147.0	153.6	300.6	305
45	165.4	194.4	359.8	360
50	183.8	240.0	423.8	425
55	202.1	290.3	492.4	495
60	220.5	345.5	566.0	570
65	238.9	405.5	644.4	645
70	257.3	470.3	727.6	730
75	275.6	539.9	815.5	820
80	294.0	614.3	908.3	910

(From the AASHTO "Green Book" Section 3.2.2, Table 3-1)

TABLE 100.4 – Stopping Site Distance on Grades

Design Speed (mph)	Stopping Site Distance (ft)					
	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
15	80	82	85	75	74	73
20	116	120	126	109	107	104
25	158	165	173	147	143	140
30	205	215	227	200	184	179
35	257	271	287	237	229	222
40	315	333	354	289	278	269
45	378	400	427	344	331	320
50	446	474	507	405	388	375
55	520	553	593	469	450	433
60	598	638	686	538	515	495
65	682	728	785	612	584	561
70	771	825	891	690	658	631
75	866	927	1003	772	736	704
80	965	1035	1121	859	817	782

(From the AASHTO "Green Book" Section 3.2.2, Table 3-2)

100.4.5 Small Deflection Angles

For small deflection angles, curves should be sufficiently long to avoid the appearance of a kink. Curves should be at least five hundred (500) feet long for a central angle of five degrees (5^o), and the minimum length should be increased one hundred feet (100') for each one-degree (1^o) decrease in the central angle. Horizontal curves should not be used when the central angle is fifty-nine minutes (59') or less. This criteria applies to arterial roadway design only.

100.4.6 Compound Curves

A compound curve on arterials should be avoided, particularly where a simple curve can be obtained at small extra cost. Where topography makes their use necessary, the radius of the flatter curve should not be more than fifty percent (50%) greater than the radius of the sharper curve. When this is not feasible, an intermediate curve or spiral should be used to provide the necessary transitions. Spiral curves are only to be used upon written approval of the City Engineer or designee.

100.4.7 Reversing Curves

True reversing curves should not be used. In cases of reversing curves, a sufficient tent should be maintained to avoid overlapping of the required superelevation runoff and tangent runout. The following is the minimum tangent lengths that shall be used for each roadway classification:

A. Local -- not applicable.

B. Collector – One hundred feet (100') minimum.

C. Arterial -- One hundred fifty feet (150') minimum.

100.4.8 Broken-Back Curves

A broken-back curve consists of two (2) curves in the same direction joined by a short tangent, of length less than one thousand five hundred feet (1500'). Broken-back curves are undesirable. If the length of intervening tangent is less than one thousand five hundred feet (1500'), a simple curve, a compound curve, or spiral transitions should be used to provide some degree of continuous superelevation. Spiral curves are only to be used upon written approval of the City Engineer or designee.

100.4.9 Alignment at Bridges

Ending a curve on a bridge is undesirable and adds to the complication of design and construction. Likewise, curves beginning or ending near a bridge should be so placed that no part of the spiral or superelevation transitions extends onto the bridge. Compound curves on a bridge are equally undesirable. If curvature is unavoidable, every effort should be made to keep the bridge within the limits of the simple curve.

100.4.10 Coordination With Vertical Alignment

To avoid the possibility of introducing serious traffic hazards, coordination is required between horizontal and vertical alignment. Particular care must be exercised to maintain proper sight distance at all times. Sharp horizontal curves introduced at or near the top of pronounced crest or bottom of sag vertical curves should be avoided.

100.4.11 Railroad Crossings

All railroad crossings on arterial streets shall be steel reinforced rubber for the full width of the roadway. A timber pedestrian walk and vehicle recovery area shall be provided on both sides of the steel reinforced rubber.

Timber crossings may be used in place of steel reinforced rubber on local streets only. Minimum crossing width shall be the full width of the right-of-way to provide for pedestrians and vehicle recovery area.

All railroad crossings must be approved by the appropriate railroad company.

100.5 VERTICAL ALIGNMENT

100.5.1 Permissible Roadway Grade

The minimum desirable grade for roadways is one percent (1%), but can be as low as one-half percent (.5%) with approval of the City Engineer or designee. The maximum allowable grade for any roadway is shown in the Vertical Alignment Control Table below. The City Engineer or designee may permit deviations from these requirements when, in his judgment, terrain conditions are such that maximum grades as set forth are not feasible.

Table 100.5

Vertical Alignment Control Table		
Description	Design Speed*	Maximum Grade**
Local	35	8
Minor Collector	40	7
Major Collector	50	7
Minor Arterial	50	6
Major Arterial***	55	6

* The design speed is a minimum of 5 miles per hour over the posted speed for each classification.

** The maximum grades indicated should only be used in extreme topographic conditions. The designer should strive to minimize the use of these grades for considerable lengths and on north-facing slopes.

*** K values exceeding 125 on curbed streets should be checked for drainage. Multiple inlets may be required within long sag on vertical curves, and where the longitudinal slope is less than 0.4 percent.

100.5.2 Permissible Intersection Grades (Public Rights-of-Way)

The maximum permissible grade at intersections shall be as shown in the table below. These grades are maximum instantaneous flowline grades for the stated distances (each side of the street) for the minor (intersecting) street.

TABLE 100.6

Maximum Grades and Length of Grades at Intersection Approaches				
Intersection of:	Local	Collector	Arterial	Maximum Grade
Local Street with	35’	100’	100’	4%
Collector Street with	100’	100’	200’	3%
Arterial Street with	125’	200’	200’	2%

The intersection grade of the major (through) street at the intersection may be dictated by design considerations for the street. However, if the major street intersection grade exceeds three percent (3%), the type of access and access control will be as directed by the City Engineer or designee.

All private commercial driveways with curb return radii have a maximum grade of 4%, with the length of the maximum grade for the commercial driveway a minimum of fifty feet (50') measured from the flowline intersection of the public roadway.

100.5.3 Changing Grades

Continuous grade changes shall not be permitted. The use of grade breaks in lieu of vertical curves is discouraged. However, if a grade break is necessary and the algebraic difference in grade does not exceed four-tenths of a percent (0.004 ft./ft.) along the roadway, the grade break will be permitted. The maximum grade break allowed at the point of tangency at a curb return for local and collector roads shall be two percent (2%) and a maximum of one percent (1%) for arterial roadways.

100.5.4 Vertical Curves

When the algebraic difference in grade (A) is at, or exceeds, four-tenths of a percent, (0.004 ft./ft.) a vertical curve is to be used. All vertical curves shall be symmetrical. The minimum gradients into and out of a sag (sump) vertical curve is five-tenths of a percent (0.005 ft./ft.). All vertical curves shall be labeled in the profile with length of curve (L), K=L/A values, VPC, VPT, VPI, and stationing and elevation of these components. In addition, the low point or high point of the vertical curve shall be shown. The minimum vertical curve design criteria in accordance with the 2011 6^{th} Edition of the AASHTO “Green Book” Section 3.4.6 is shown in Table 100.7A and Table 100.7B.

TABLE 100.7A – Design Controls for Crest Vertical Curves Based on Stopping Sight Distance

Design Speed (mph)	Stopping Sight Distance (ft)	Rate of Vertical Curvature, K	
		Calculated	Design
15	80	3.0	3
20	115	6.1	7
25	155	11.1	12
30	200	18.5	19
35	250	29.0	29
40	305	43.1	44
45	360	60.1	61
50	425	83.7	84
55	495	113.5	114
60	570	150.6	151
65	645	192.8	193
70	730	246.9	247
75	820	311.6	312
80	910	383.7	384

(From the AASHTO “Green Book” Section 3.4.6, Table 3-34)

TABLE 100.7B – Design Controls for Sag Vertical Curves

Design Speed (mph)	Stopping Sight Distance (ft)	Rate of Vertical Curvature, K	
		Calculated	Design
15	80	9.4	10
20	115	16.5	17
25	155	25.5	26
30	200	36.4	37
35	250	49.0	49
40	305	63.4	64
45	360	78.1	79
50	425	95.7	96
55	495	114.9	115
60	570	135.7	136
65	645	156.5	157
70	730	180.3	181
75	820	205.6	206
80	910	231.0	231

(From the AASHTO “Green Book” Section 3.4.6, Table 3-36)

* K values exceeding 125 on curbed streets should be checked for drainage. Multiple inlets may be required within long sag on vertical curves, and where the longitudinal slope is less than 0.4 percent.

Maximum desirable grade for local streets is 8%, a collector is 7%, and arterial is 6%. Maximum grades should only be used in extreme topographic conditions, and the designer should strive to minimize the use of maximum grades for considerable lengths.

Grades in excess of the maximum desirable must be approved by the City Engineer or designee.

100.5.5 Intersections

In addition, the following criteria shall apply at intersections.

A. The grade of the "through" street shall take precedence at intersections. At the intersections of roadways with the same classification, the more important roadway, as determined by the City Engineer or designee, shall have this precedence. The design should warp side streets to match through streets with as short a transition as possible.

B. The key criteria for determining the elevation of the curb return on the side street and the amount of warp needed on a side street transitioning to a through street are:

1. Permissible grade in the stop/start lane. See 100.5.2 of these Standards.

2. Pavement cross slope at the PCR's on the side street and permissible warp in pavement cross slope (see Section 100.7.1(B)).

3. Normal vertical curve criteria.

4. Vertical controls within the curb return itself.

C. The elevation at the PCR of the curb return on the through street is always set by the grade of the through street in conjunction with pavement cross slope.

D. Carrying the crown at a side street into the through street is permitted only when drainage considerations warrant such a design.

E. A more detailed review shall be performed for arterial-arterial intersections to maximize driveability. A few arterial intersections will have a uniform two percent (2%) cross-slope, the majority of them having one or more sides warped.

F. Whenever possible, intersections shall be made at right angles or radial to a curve. No intersecting angle of less than eighty degrees (80^{o}) will be allowed without approval of the City Engineer or designee.

100.5.6 Curb Returns

Minimum fall around curb returns for flow along the curb line shall be as follows:

TABLE 100.8

CURB RETURNS	
Radius	Minimum Fall
18 Feet	0.3 Feet
25 Feet	0.4 Feet
30 Feet	0.4 Feet
50 Feet	0.5 Feet
All Others	1.2 Percent Around the Return

100.5.7 Curb Return Profiles

Curb return profiles are required for radii equal to or greater than thirty (30') within the public right-of-way. A mid-point elevation along the arc length of the curb return shall be shown in plan view for radii equal to or greater than twenty-five feet (25'). Curb return design shall be set in accordance with the following design procedure. General standards for flowline control and profiles with the curb returns shall be as follows:

A. The point of tangency at each curb return shall be determined by the projected tangent grade beginning at the point of intersection (PI) of the flowlines.

B. The arc length and external distances of the curb return shall be computed and indicated on the drawing.

C. Show the corresponding flowline (or top of curb) grade for each roadway beyond the PCR.

D. Design the curb return flowline such that a maximum cross slope between the mid-point of the curve and the PICR (external distance) does not exceed five percent (5%). Grade breaks at the PCRs shall not exceed two percent (2%) for local and collector streets and one percent (1%) for arterials. The flowline design of the curb return shall be accomplished within the return without affecting street grades beyond the PCR. Maximum vertical curves will equal the arc length of the curb return. The elevation and location of the high or low point within the return, if applicable, is to be called out in the profile.

E. Scale for the curb return profile to be one inch equals one foot (1"=1’) vertically and one inch equals ten feet (1”=10’) horizontally.

F. Curb return radii, existing and proposed, shall be shown.

100.5.8 Connection With Existing Roadways

A. Connection with existing roadways shall be smooth transitions conforming to normal vertical curve criteria if the algebraic difference in grade between the existing and proposed grade exceeds four-tenths (0.004 ft./ft.) of a percent. When a vertical curve is used to make this transition, it shall be fully accomplished prior to the connection with the existing improvements and shall also comply with the grade requirements at intersection approaches.

B. Existing grade shall be shown for at least three hundred feet (300') with field verified as-builts showing stations and elevations at twenty-five-foot (25') intervals. In the case of connection with an existing intersection, these as-builts are to be shown within a three-hundred-foot (300') radius of the intersection. This information will be included in the plan and profile that shows that proposed roadway. Limits and characteristics of the proposed improvement are the primary concern in the plan view. Such characteristics include horizontal alignment, off-site intersections, limits of the improvement, etc.

C. Previously approved designs for the proposed improvement are not an acceptable means of establishing existing grades. However, they are to be referenced on the construction plan where they occur.

D. The basis of the as-built elevations shall be the design elevations (both flowline or both top of curbs, etc.) when possible.

100.5.9 Off-Site Design

The design grade, and existing ground at that design grade, of all roadways that dead end due to project phasing, subdivision boundaries, etc., shall be continued, in the same plan and profile as the proposed design, for at least five hundred (500) feet or to its intersection with an arterial roadway. This limit shall be extended to one thousand (1,000) feet when arterial roadways are being designed.

If the off-site roadway, adjacent to the proposed development is not fully improved, the developer is responsible for the design and construction of a transition for the safe conveyance of traffic from his improved section to the existing roadway. The following formula shall be applied to determine the taper length for road with a speed of less than 45 MPH:

$$L = WS^2/60$$

where

L = Length of transition in feet
W = Width of offset in feet
S = Speed limit or 85^{th} percentile speed in MPH.

100.6 INTERSECTION AND DRIVEWAY SIGHT DISTANCES

100.6.1 General

Adequate intersection design necessitates the provision of safe ingress and egress from one street or driveway to the other, based in part on the ability of a driver to see oncoming vehicles or pedestrians. The following guidelines shall be used in the design of intersections, private driveways and public streets that intersect other traffic carrying facilities.

100.6.2 Intersection Sight Distance

Different types of vehicular conflicts have the potential to occur at every intersection and may be reduced when appropriate sight distances and traffic controls are provided. Two different types of sight triangles are considered in intersection design: approach sight triangles and departure sight triangles (AASHTO, p. 9-29).

Approach Sight Triangles
Each quadrant of an intersection should contain a triangular area free of obstructions that may block an approaching driver's view of potentially conflicting vehicles (AASHTO, p. 9-29). The length of the legs of the triangular area, along both intersecting roadways, should be such that the drivers can see any potentially conflicting vehicles in sufficient time to slow or stop before colliding within the intersection (AASHTO, p. 9-29). Standard Drawing ST-16 shows the clear sight distance triangles to the left and to the right for a vehicle approaching an uncontrolled or yield-controlled intersection (AASHTO, p. 9-29, 9-30). The vertex of the sight triangle on a minor road uncontrolled approach represents the decision point for the minor road driver as shown in Standard Drawing ST-16 (AASHTO, p. 9-30). The distance from the major road, along the minor road, is illustrated by the distance A1 to the left and A2 to the right (AASHTO, p. 9-30). Distance A2 is equal to distance A1 plus the width of the lane(s) departing from the intersection on the major road to the right (AASHTO, p. 9-30). Distance B represents the length of the leg of the sight triangle when a driver of a vehicle without the right-of-way sees a vehicle that

has the right-of-way on an intersecting approach, the driver of that potentially conflicting vehicle can also see the first vehicle (AASHTO, p. 9-30).

Departure Sight Triangles

Departure sight triangles provide sight distance sufficient for a stopped driver on a minor road approach to depart from the intersection and enter or cross the major road (AASHTO, p. 9-31). The departure triangles to the left and right of the location of a stopped vehicle on the minor road is shown in Standard Drawing ST-17 (AASHTO, p. 9-31). Departure sight triangles should be provided in each quadrant of each intersection approach controlled by stop signs and sometimes at signalized intersection approaches (AASHTO, p. 9-31). Distance A2 as shown in Standard Drawing ST-17 is equal to distance A1 plus the width of the lane(s) departing from the intersection on the major road to the right (AASHTO, p. 9-31).

When determining whether an object is considered to be a sight obstruction, the horizontal and vertical alignment of both intersecting roadways as well as the height and position of the object should be analyzed (AASHTO, p. 9-31). It should be assumed that the driver's eye is 3.50 feet above the road surface and the object to be seen is 3.50 feet above the road surface (AASHTO, p. 9-31). Within the area of the sight triangle there should be no wall, fence, sign, foliage, berm, or other structure that would obscure the driver's view of traffic approaching the intersection. The structures or berms within the sight distance triangle can extend no higher than 24 inches (2.0 feet) above the curb elevation and no lower than 96 inches (8 feet) above the curb. Exceptions to this requirement exist for public facilities such as fire hydrants, utility poles, and traffic control devices. These facilities must be located to minimize visual obstructions.

Intersection Control

The recommended dimensions of the sight triangles vary with the type of traffic control used at an intersection because different types of control impose different constraints on drivers and, therefore result in different driver behavior (AASHTO, p. 9-32). Procedures to determine sight distances at intersections shall be in accordance with the 2011 6th Edition of the AASHTO "Green Book" Section 9.5.3 for the Cases below:

Case A – Intersections with no control

Case B – Intersections with stop control on the minor road

- Case B1 – Left turn from the minor road
- Case B2 – Right turn from the minor road
- Case B3 – Crossing maneuver from the minor road

Case C – Intersections with yield control on the minor road

- Case C1 – Crossing maneuver from the minor road
- Case C2 – Left or right turn from the minor road

Case D – Intersections with traffic signal control

Case E – Intersections with all-way stop control

Case F – Left turns from the major road

Table 100.9 – Length of Sight Triangle Leg – Case A, No Traffic Control

Design Speed (mph)	Length of Leg (ft)
15	70
20	90
25	115
30	140
35	165
40	195
45	220
50	245
55	285
60	325
65	365
70	405
75	445
80	485

(From the AASHTO “Green Book” Section 9.5.3, Table 9-3)

Table 100.10 Design Intersection Sight Distance – Case B1, Left Turn from Stop

Design Speed (mph)	Stopping Sight Distance (ft)	Intersection Sight Distance for Passenger Cars	
		Calculated (ft)	Design (ft)
15	80	165.4	170
20	115	220.5	225
25	155	275.6	280
30	200	330.8	335
35	250	385.9	390
40	305	441.0	445
45	360	496.1	500
50	425	551.3	555
55	495	606.4	610
60	570	661.5	665
65	645	716.6	720
70	730	771.8	775
75	820	826.9	830
80	910	882.0	885

(From the AASHTO “Green Book” Section 9.5.3, Table 9-6)

Table 100.11 Design Intersection Sight Distance – Case B2, Right Turn from Stop, and Case B3, Crossing Maneuver

Design Speed (mph)	Stopping Sight Distance (ft)	Intersection Sight Distance for Passenger Cars	
		Calculated (ft)	Design (ft)
15	80	143.3	145
20	115	191.1	195
25	155	238.9	240
30	200	286.7	290
35	250	334.4	335
40	305	382.2	385
45	360	430.0	430
50	425	477.8	480
55	495	525.5	530
60	570	573.3	575
65	645	621.1	625
70	730	668.9	670
75	820	716.6	720
80	910	764.4	765

(From the AASHTO “Green Book” Section 9.5.3, Table 9-8)

Table 100.12 Case C1 – Crossing Maneuvers from Yield-Controlled Approaches, Length of Minor Road Leg and Travel Times

Design Speed (mph)	Minor-Road Approach		Travel Time (S)	
	Length of Leg (ft)	Travel Time (S)	Calculated Value	Design Value
15	75	3.4	6.7	6.7
20	100	3.7	6.1	6.5
25	130	4.0	6.0	6.5
30	160	4.3	5.9	6.5
35	195	4.6	6.0	6.5
40	235	4.9	6.1	6.5
45	275	5.2	6.3	6.5
50	320	5.5	6.5	6.5
55	370	5.8	6.7	6.7
60	420	6.1	6.9	6.9
65	470	6.4	7.2	7.2
70	530	6.7	7.4	7.4
75	590	7.0	7.7	7.7
80	660	7.3	7.9	7.9

(From the AASHTO “Green Book” Section 9.5.3, Table 9-9)

Table 100.12A Length of Sight Triangle Leg along Major Road – Case C1, Crossing Maneuver at Yield-Controlled Intersections

Major Road Design Speed (mph)	Stopping Sight Distance (ft)	Design Values (ft) Minor-Road Design Speed (mph)							
		15	20-50	55	60	65	70	75	80
15	80	150	145	150	155	160	165	170	175
20	115	200	195	200	205	215	220	230	235
25	155	250	240	250	255	265	275	285	295
30	200	300	290	300	305	320	330	340	350
35	250	345	335	345	360	375	385	400	410
40	305	395	385	395	410	425	440	455	465
45	360	445	430	445	460	480	490	510	525
50	425	495	480	495	510	530	545	570	585
55	495	545	530	545	560	585	600	625	640
60	570	595	575	595	610	640	655	680	700
65	645	645	625	645	660	690	710	740	755
70	730	690	670	690	715	745	765	795	815
75	820	740	720	740	765	795	820	850	875
80	910	790	765	790	815	850	875	910	930

(From the AASHTO "Green Book" Section 9.5.3, Table 9-10)

Table 100.13 Design Intersection Sight Distance – Case C2, Left or Right Turn at Yield-Controlled Intersections

Design Speed (mph)	Stopping Sight Distance (ft)	Length of Leg	
		Passenger Cars	
		Calculated (ft)	Design (ft)
15	80	176.4	180
20	115	235.2	240
25	155	294.0	295
30	200	352.8	355
35	250	411.6	415
40	305	470.4	475
45	360	529.2	530
50	425	588.0	590
55	495	646.8	650
60	570	705.6	710
65	645	764.4	765
70	730	823.2	825
75	820	882.0	885
80	910	940.8	945

(From the AASHTO "Green Book" Section 9.5.3, Table 9-12)

Table 100.14 Intersection Sight Distance – Case F, Left Turn from the Major Road

Design Speed (mph)	Stopping Sight Distance (ft)	Length of Leg Passenger Cars Calculated (ft)	Length of Leg Passenger Cars Design (ft)
15	80	121.3	125
20	115	161.7	165
25	155	202.1	205
30	200	242.6	245
35	250	283.0	285
40	305	323.4	325
45	360	363.8	365
50	425	404.3	405
55	495	444.7	445
60	570	485.1	490
65	645	525.5	530
70	730	566.0	570
75	820	606.4	610
80	910	646.8	650

(From the AASHTO "Green Book" Section 9.5.3, Table 9-14)

100.7 ROADWAY CROWN

100.7.1 Cross Slope

Except at intersections or where superelevation is required, roadways shall be level from top of curb to top of curb (or flowline to flowline) and shall have a minimum two percent (2%) crown. Within one-hundred-fifty feet (150') of an intersection, the maximum elevation difference between flowlines shall be dictated by the allowable intersection grade and the actual distance between flowlines.

A. Parabolic or curved crowns are not allowed. In no case shall the pavement cross slope at warped intersections exceed the grade of the through street.

B. The rate of change in pavement cross slope when warping side streets at intersections shall not exceed one percent (1%) every twenty-five feet (25') horizontally on a local roadway, one percent (1%) every thirty-seven-and-one-half feet (37.5') horizontally on a collector roadway, or one percent (1%) every fifty-six-and-one-half feet (56.5') horizontally on an arterial roadway.

C. In the case of conflict caused by requirements of the Storm Drainage Design Section, the drainage requirements shall govern.

100.8 SIDEWALKS, CURB AND GUTTERS, RAMPS, AND DRIVEWAYS

A. Roadway typical sections shall be as specified by the Engineering Code of Standards and Specifications for the Design and Construction of Public Improvements.

B. Sidewalks and/or bicycle paths shall be constructed on both sides of all roadways as depicted in the typical sections unless specifically deleted by action of the City of Arvada.

C. ADA ramps shall be constructed in accordance with the detail drawings in these Standards. ADA ramps may be shown at all curb returns or called out by a general note on the development plans, but must be shown (located) on all "T" intersections. Whenever referencing an ADA ramp, call out the specific City of Arvada detail drawing to construct that ramp.

D. Drainage structures shall not be placed in line with ADA ramps. Location of ADA ramps shall take precedence over location of the drainage structure.

E. Curb cuts should not be used for commercial/industrial or high volume residential driveways. In general, when the number of parking spaces services by the driveway exceeds ten (10), radius returns should be used.

F. Where curb cuts are allowed based on traffic considerations, concentrated storm water runoff must not be discharged across the sidewalk. These flows must be directed to a sidewalk chase section. If this is not possible due to grading constraints, radius returns and a crosspan shall be used.

G. Curb cuts and driveways shall be constructed in accordance with the detail drawings in these Standards.

100.9 CUL-DE-SACS

The following criteria shall be used for cul-de-sac horizontal geometry (See ST-20, Cul-De-Sac Design Standard).

A. The minimum property line radius shall be fifty-five feet (55’).

B. The minimum flowline radius shall be forty-five feet (45’).

C. The maximum length of the cul-de-sac as measured along the center line, from extended property lines on the open end to the farthest side of the circumference of the turnaround shall be five hundred feet (500'). Length may be increased only with specific approval of the City Engineer or designee for special circumstances.

D. Vertical alignment shall be in accordance with Section 100.5 of these Standards.

100.10 AUXILIARY LANES (ACCELERATION AND DECELERATION LANES)

The design of the arterial street system depends upon the proper control of access to developments. The location and design of access points must minimize traffic hazards and interference to through traffic movements. To ensure proper control, the following standards for acceleration and deceleration lanes have been established. The approved traffic impact analysis study or the City Engineer or designee shall establish the need for acceleration and deceleration lanes.

Right and left turn lanes from Arterial streets shall have a minimum of 150 feet of storage length and 150 feet of transition taper. Additional storage length may be required dependent on the volume of turn movements. The Colorado Department of

Transportation State Highway Access Code should be consulted for further details on auxiliary lanes.

100.11 STREET LIGHTING

Streetlights shall be provided at all arterial street/road intersections and as required on all newly developed and dedicated public streets in the City. In general street light poles shall not be placed within sidewalks or curb ramps.

The land developer shall contact the City's Traffic Division (720-898-7740) to initiate street light design for any new development during the plan review process. The developer must provide a copy of the proposed site plan, which will be used for proposed streetlight layout design. The plan will be returned to the developer showing all required streetlights.

Construction of the new streetlights shall be coordinated between the developer, appropriate electrical utility and the electrical contractor.

100.12 SIGNING AND STRIPING

Signing/Striping plans of new streets/roads and re-signing/striping of existing streets/roads necessitated by development shall be submitted as part of the construction plans. All signing/striping shall be in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) and must be approved by the City Engineer or designee.

100.13 UTILITIES

All house service lines, main lines, etc., shall be installed according to City of Arvada "Engineering Code of Standard Specifications for the Design and Construction of Public Improvements" prior to paving of any street. All required utility trench compaction testing reports must be submitted to, reviewed and approved by the City of Arvada prior to subgrade preparation, concrete flatwork placement or paving.

100.14 DRAINAGE

All streets shall be designed to provide continuous surface drainage directed to storm drain inlets and drainage courses. Grades shall permit flow without ponding. Inlets shall be located to intercept the curb flow at the point flow capacity is exceeded by storm runoff according to the UDFCD manual. Inlets shall also be installed to intercept cross-pavement flows at points of transition in superelevation. Due to the presence of ADA ramps, inlets shall not be allowed in the curb return but shall be located outside the tangent points of the curb returns. Gutter transition sections abutting inlets shall not be within the curb return.

Eight (8) feet wide concrete crosspans shall normally be installed across those streets at intersections carrying traffic which must stop. Installation of crosspans between intersections or across streets carrying through traffic at intersections shall be avoided in all possible cases. Crosspans are not permitted across collector or arterial roadways, nor are they allowed on roadways with storm sewer systems. The use of any crosspan on roadways where the vertical grade exceeds four-and-one-half percent (4.5%) will be considered only after all alternatives have been exhausted. Mid block crosspans are discouraged and must be approved by the City Engineer or designee.

Storm water from concentrated points of discharge shall not be allowed to flow over sidewalks but shall drain to the roadway or storm inlet by use of chase sections. Sidewalk chase sections shall not be located within a curb cut or driveway. Hydraulic design shall be in accordance with Section 105 of these Specifications. Sidewalk chases will only be allowed where approved by the City Engineer or designee. Sidewalk chases, when permitted, are to be used to allow surface drainage to enter into the street gutter, rather than being used to avoid the use of a standard inlet. Sidewalk chase sections shall be constructed in accordance with Detail Drawing ST-12.

A check shall be made to be sure of continuity of drainage design between the proposed construction and existing of future construction. In no case shall surface drainage be permitted to be disposed of overland except by approved storm drainage facilities. See Section 105 of these Specifications for design requirements.

100.15 SUBGRADE INVESTIGATION FOR PAVEMENT DESIGN

General
All pavement designs shall be based on the minimum subgrade investigations as outlined below.

All subgrade investigations shall be completed by or under the supervision of and signed by a Professional Engineer registered in the State of Colorado.

Field Investigation
The field investigation shall consist of borings or other suitable methods of sampling subgrade soils to a depth of at least 5 feet below proposed subgrade elevation (10 feet below proposed subgrade on arterial roadways), at spacings of not more than 250 feet unless otherwise accepted by the Engineering Division. Every fifth hole shall be 10 feet deep and cased to determine groundwater level. Where the length of the proposed new street is less than 250 feet, two borings shall be made. Samples shall be taken after grading is completed and the subgrade is rough cut. California Drive samples shall be obtained from each boring within 12-18 inches of the final subgrade elevation.

Classification Testing
Each subgrade sample shall be tested to determine Liquid Limit, Plastic Limit, Plasticity Index, Atterberg Limits and the percentage passing the U.S. Standard No. 200 sieve. Samples of sands and gravels may require gradation analysis for classification determination. These data shall be determined using the following methods:

Liquid Limit - AASHTO T 89 (ASTM D 4318)
Plastic Limit - AASHTO T 90 (ASTM D 4318)
% Passing No. 200 - AASHTO T 11 (ASTM C 117)
Gradation - AASHTO T 27 (ASTM D 422)

The results of these tests shall be used to calculate the AASHTO Classification and Group Index using AASHTO M 145.

Soil Grouping
To facilitate subgrade support testing, soil samples collected in the field investigation can be combined to form soil groups. These groups shall be based upon the AASHTO Classification, Group Index and location within the area investigated. Groupings shall not consist of samples with different AASHTO Classifications (Note: there may be more than one group within a given classification). Composite samples can be manufactured by combining representative, equal portions of each subgrade sample contained within the group and mixing to provide a uniform composite sample of the soil group. Composite samples shall be subjected to Classification Testing as outlined in AASHTO M 145. Moisture density curves must be included for groups used in the design.

Subgrade Support Testing
Individual subgrade or composite samples shall be tested to determine the subgrade support value using either CBR (California Bearing Ratio) or Hveem Stabilometer (R-value) testing. These values shall be used in the design of pavement sections in accordance with the procedures outlined in Section 100.16. Tests shall be conducted in accordance with the procedures listed below.

CBR Tests - California Bearing Ratio tests shall be conducted in accordance with AASHTO T 193 with the following modifications:

A. Note 4 of AASHTO T 193 shall not apply. A 3 point CBR evaluation is required.

B. The compaction method for the CBR test shall be determined by the soil classification.

C. Surcharge shall be calculated using a unit weight of 140 pcf for bituminous pavement and 135 pcf for untreated aggregate base course.

D. The design CBR value shall be determined from the CBR -- Dry Density Curve and shall be the CBR value at 95 percent of maximum standard proctor density (ASTM D-698) at +/- 2% of optimum moisture content.

E. In addition to the values requested in AASHTO T 193, Stress-Penetration curves for each sample, a CBR - Dry Density curve and Proctor Compaction test results shall be reported.

R-Value Tests - Hveem Stabilometer tests shall be conducted in accordance with AASHTO T 190. The design R-value shall be at 300 psi exudation pressure. The reported data shall consist of:

A. Dry density and moisture content for each sample.

B. Expansion pressure for each sample.

C. Exudation Pressure - corrected R-value curve showing the 300 psi design R-value.

Swell Test - A Colorado Swell Test (also referred to as the Denver Swell Test or Swell Consolidation Test) shall be required in all pavement design reports for each soil group.

If the swell (at an overburden pressure of 400 psf, at specified compaction per CDOT and at optimum moisture content) is 2.0% or greater, the pavement design report must provide mitigative measures to minimize the destructive swell potential. Since the pavement is not placed on the soils until after the soil has been winrowed, moisture treated, and compacted to optimum, the "% swell" shall be measured from the point after the overburden pressure is applied, to the point after water is added. In other words, after the overburden pressure is applied and consolidation has occurred, the "% swell" = 0.0%, then add water and measure the swell. Mitigation could be over excavation and replacement with suitable non-expansive material to a depth sufficient to protect the pavement, lime treatment, soil cement, french drains, or other procedures acceptable to the Engineer and as recommended and supported by a Geotechnical Engineer. Moisture treatment, by itself, may not be an adequate mitigative measure. If expansive soil mitigation is made, the soil treatment shall extend to the back-of-curb (if detached walk or no walk), or to the back-of-walk (if attached or monolithic walk).

100.16 PAVEMENT DESIGN CRITERIA

General

This section provides the parametric input data to be used for the design of pavements of various roadway classifications. A final pavement design shall be completed and submitted after City of Arvada approval of the associated construction plans and prior to subgrade preparation and paving. All pavement designs shall be completed by or under the supervision of and signed by a Professional Engineer registered in the State of Colorado. Pavement design reports shall include site specific stabilization recommendations for subgrade preparation.

Equivalent (18 Kip) Daily Load Applications (EDLA)

The pavement design procedure in this Section provides for a 20 year service life of pavement, given that normal maintenance is provided to keep roadway surface in an acceptable condition. EDLA and Design Traffic Number (DTN) are considered equivalent units based on 20 year design criteria and an 18 kip axle loading. All data and design nomographs in this section of the Specifications use EDLA units for pavement loading repetitions.

EDLA criteria for each City of Arvada roadway classification is given in Table 100.15 below.

TABLE 100.15

RECOMMENDED EQUIVALENT (18 Kip) DAILY

LOAD APPLICATIONS (EDLA)

CLASSIFICATION	CLASS MODIFIER	EDLA VALUES[1]
Local	Residential	
	Serving <50 D.U.	8
	All Others	10
	Commercial[2]	30
	Industrial[2]	100
Entry	Residential	10
Minor Collector	Residential	30
	Commercial[2]	50
	Industrial[2]	150
Major Collector[2]	Residential	100
	Commercial[2]	100
	Industrial[2]	150
Minor Arterial[2]	All	200
Major Arterial[2]	All	200
Entry Street		10
	EDLA MINIMUM (EDLA may be required to be 30 if number of DU's served is over 100)	

Notes: [1]Alternative EDLA values may be considered with justification provided by the Traffic Impact Study, proposed land uses, and traffic analysis that defines proportion of truck vehicles including construction truck traffic.

[2]EDLA shall be calculated based on projected traffic uses. EDLA values prescribed are minimum.

Design Serviceability

The following criteria shall be used for all City of Arvada roadways to be dedicated for public use:

TABLE 100.16

SERVICEABILITY INDEX

ROADWAY CLASSIFICATION	SI
ARTERIALS	2.5
COLLECTORS	2.5
LOCAL	2.0

Minimum Pavement Section

This following Table 100.17 provides the minimum acceptable pavement sections for public roadways in the City of Arvada. These pavement thicknesses may be used for preliminary planning purposes. Final pavement designs must be based on actual subgrade support test results. The following table lists these minimum thicknesses for each roadway classification.

TABLE 100.17

RECOMMENDED MINIMUM PAVEMENT SECTIONS

		COMPOSITE SECTION			
CLASSIFICATION	**EDLA**	**ASPHALT (Inches)**	**TREATED SUBGRADE OR BASE (Inches)**	**FULL DEPTH ASPHALT (Inches)**	**PORTLAND CEMENT CONCRETE (Inches)**
Local					
Residential	(Table 100.15)	5	6	6	6
Commercial	30	5	6	6	6
Industrial	100	6	6	6	6
Minor Collector					
Residential	30	5	6	7	6
Commercial	50	6	6	7	6
Industrial	150	6.5	6	7.5	6
Major Collector					
Residential	100	6	6	7	6
Commercial	100	6	6	7	6
Industrial	150	6.5	6	7.5	6
Minor Arterial	200	7	6	8	6
Major Arterial	200	7	6	9	6

Expansive soil subgrades shall be sub excavated and replaced with acceptable moisture conditioned fill. Minimum sub excavation requirements are shown in Table 100.18 as determined by the highest percentage of swell recorded. Sub excavation areas shall be recompacted to 95% of maximum standard proctor density (ASTM D-698) at 0 to +4% above optimum moisture content.

Table 100.18
MOISTURE TREATMENT REQUIREMENTS

Swell Potential*	Depth of Moisture Treatment	Depth of Chemical Stabilization
<3% swell	Moisture treat to a depth of 1’	___
>3% <5% swell	Moisture treat to a depth of 2.5’ or	___
	Moisture treat to a depth of 1.5’	Stabilization treat to a depth of 1’
>5% swell	Moisture treat to a depth of 1.5’	Stabilization treat to a depth of 1’

*Indicated average percentage of swell as recorded to the nearest whole number.

NOTE: From the top of finished grade, moisture treatment **shall not** go deeper than 30” without written direction from the engineer.

Soils with >5% swell shall also require stabilized subgrade swell mitigation per Section 15 STREETS, in addition to moisture treatment.

Flexible Pavement Strength Coefficients

Table 100.19 below contains the standard design coefficients for various pavement materials. Nonstandard design coefficients may be used only if approved in advance by the Engineer. In addition, design values must be verified by predesign mix test data and supported by daily construction tests; or, redesign values will be required.

TABLE 100.19
STRENGTH COEFFICIENTS

PAVEMENT STRUCTURE COMPONENT*	STRENGTH COEFFICIENTS	(LIMITING TEST CRITERIA)
CONVENTIONAL MATERIALS		
Plant Mix Seal Coat	.25	
Hot Bituminous Pavement	.40	(1500 lbs. Marshall or Rt 90+)
Exist Bituminous Pavement	.30 .24	(9-15 yr.) (>15 yr.)
Aggregate Base Course	.12	(CBR 80+ or R 78+)
Exist Aggregate Base Course	.10	(CBR 50+ or R 69+)
Granular Subbase Course	.07	(CBR 15 or R 50+)
TREATED MATERIALS		
Cement Treated Aggregate Base	.23	(7 day, 640-1000 psi)
Lime Treated Subgrade All Stabilized Subgrade	.14	(7 day, 160 psi, PI <6, net swell <0.5%, PH >12.3)

*****The combination of one or more of the following courses placed on a subgrade to support the traffic load and distribute it to the roadbed.

A. Subbase. The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course, surface course or both.

B. Base Course. The layer or layers of specified or selected material of designed thickness placed on a subbase or a subgrade to support a surface course. The use of base course will not be allowed in areas that base course does not adequately drain from roadway system.

C. Surface Course. One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer is sometimes called "Wearing Course."

Portland Cement Concrete Working Stress ($f_{t.}$)

The working stress (ft.) to be used in the design shall be 75% of that provided by third-point beam loading which shall have a minimum laboratory 28-day strength of 600 psi based on actual tests of materials to be used.

100.17 PAVEMENT DESIGN PROCEDURE

Flexible Pavements

The following procedure should be used in determining the Structural Number (SN) of the pavement being designed:

A. Determine roadway classification and corresponding EDLA (Table 100.15)

B. Determine the Serviceability Index (SI) of the roadway classification (Table 100.16)

C. Select the proper nomograph:

Flexible Pavements with SI=2.0 (Standard Drawing ST-5)
Flexible Pavements with SI=2.5 (Standard Drawing ST-6)

D. Using subgrade CBR or R-value test results and EDLA, determine the SN from the appropriate design nomograph.

E. Once the Structural Number (SN) has been determined, the design thickness of the pavement structure can be determined by the general equation given below. The minimum pavement sections table (Table 100.17) shall govern when thinner sections are indicated.

$SN = a_1D_1 + a_2D_2 + a_3D_3 + ...$

where

a_1 = Hot Bituminous Pavement (HBP) strength coefficients

a_2, a_2, a_n. = strength coefficients of additional pavement components

D_1 = thickness of Hot Bituminous Pavement (HBP) (inches)

D_2, D_3, D_n = thickness of additional pavement component sections

The strength coefficients for various components of the pavement structure are given in Table 100.19.

The component thickness selected must meet two conditions.

1. Total HBP thickness selected cannot be less than the minimum specified in the minimum pavement sections table above for the roadway classification.
2. The base course thickness selected cannot exceed 2.5 times the HBP thickness selected.

F. The design must reference any mitigation measures required when the subgrade contains swelling soils (swell potential >2.00% under 400 psf surcharge pressures at 95% standard Proctor density (ASTM D-698) from a Colorado (Denver) Swell Test; moisture treatment may not be an adequate mitigative procedure). Design reports recommending permeable layers such as untreated aggregate base course in the pavement system, must present the measures to be used to ensure adequate drainage of such layers, and to maintain segregation of the layers from the swelling soils. It is required that soils with R-values less than 10 or swell potential greater than 2.00% be stabilized. Stabilization shall be as a minimum the upper 12 inches below the pavement section. If expansive soil mitigation is made, the soil treatment shall extend to the back-of-curb (if detached walk or no walk), or to the back-of-walk (if attached or monolithic walk). If lime stabilization is recommended, sulfate tests at minimum 500 foot intervals along the roadway shall be collected. Lime stabilization shall not be allowed for subgrades with sulfate concentrations in excess of 0.1%.

Rigid Pavements

The design of rigid pavements is a function of structural quality of the subgrade soil (R-value or CBR), traffic (EDLA), and the strength of the concrete (working stress). In comparison to the strength of the concrete slab, the structural contributions of underlying layers to the capacity of the pavement are relatively insignificant. Therefore, the use of thick bases or subbases under concrete pavement to achieve greater structural capacity is considered to be uneconomical and will not be considered.

Use of Rigid Pavements will only be allowed with written permission of the Engineer. Use of rigid pavements is prohibited where underlying soils have a PI greater than 10.

Use the following procedure to obtain required thickness:

A. Determine roadway classification and corresponding EDLA

B. Determine design Serviceability Index (SI) of the roadway

C. The working stress of the concrete (ft. is to be obtained from laboratory tests. For preliminary design, this value shall be assumed to be 450 psi until laboratory tests have been completed.

D. Select the proper nomograph

Rigid Pavement with SI=2.0 (Standard Drawing ST-7)
Rigid Pavement with SI=2.5 (Standard Drawing ST-8)

E. Using EDLA and working stress data, locate point on the pivot line; connect this point to the R-value or CBR value on the soil support scale to determine slab thickness.

F. Use slab thickness from step 5 or the minimum thickness from Table 100.17.

G. The design must reference any mitigation measures required when the subgrade contains swelling soils (swell potential greater than 2.00% under 400 psf surcharge pressures at 95% standard Proctor density (ASTM D-698) from Colorado (Denver) Swell Test; moisture treatment may not be an adequate mitigative procedure. Design reports recommending permeable layers such as untreated aggregate base course in the pavement system, must present the measures to be used to ensure adequate drainage of such layers, and to maintain segregation of the layers from the swelling soils. If expansive soil mitigation is made, the soil treatment shall extend to the back-of-curb (if detached walk or no walk), or to the back-of-walk (if attached or monolithic walk).