CHAPTER 5C-2 GEOMETRIC DESIGN ELEMENTS

A. General

The design values listed are primarily for urban streets with curbs and gutters. For rural designs, refer to the applicable sections, tables, and figures in SUDAS Chapter 5.

B. Sight Distance

The Project Engineer should check the AASHTO Green Book when specific information is needed. This includes stopping sight distance, passing sight distance, and intersection sight distance. Intersection sight distance should be provided at every intersection per the AASHTO Green Book.

On horizontal curves, horizontal alignment must provide at least the minimum stopping distance for the design speed at all points. This includes visibility at intersections as well as around curves and roadside encroachments.

Where an object off the pavement restricts sight distance, the minimum radius of curvature is determined by the stopping sigh distance. In no case shall the stopping sight distance be less than as specified in this chapter. A possible obstruction may be a bridge abutment or line of columns, wall, cut side slope or a side or corner of a building. The sight distance design shall assume 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. Refer to the AASHTO Green Book for specific details on sight distance on horizontal curves.

C. Horizontal Alignment

1. Roadway Curvature and Superelevation:

On urban streets where operating speed is relatively low and variable, the use of superelevation for horizontal curves is not encouraged. Although superelevation is advantageous for traffic operation, in urban areas the combination of wide pavements, the need to meet the grade of adjacent properties, the desire to maintain low speed operation, the need to maintain pavement profiles for drainage, and the frequency of cross streets and driveways and other urban features often combine to make the use of superelevation impractical or undesirable.

Generally, the absence of superelevation on low speed urban streets is not detrimental to the motorist and superelevation is not typically provided on urban streets with a design speed of 45 mph or less. The preferred radii shown in the design tables assume that a normal crown is maintained around a horizontal curve. With a standard 2.5% pavement cross-slope, this effectively results in a negative 2.5% superelevation for the outside lane. For roadways with a cross-slope other than 2.5%, including four lane and wider sections that utilize a steeper cross-

slope for the outside lanes, the required curve radius should be determined from the guidance provided in the current AASHTO "Green Book".
While superelevation on low speed urban roadways is not desirable, it may be necessary in situations where site conditions require a horizontal curve that cannot sustain traffic with the negative superelevation that results from maintaining the normal crown. For these situations, superelevation equal to the normal cross-slope may be provided for the outside lane. The maximum superelevation for low speed urban roadways should not exceed the normal cross-slope or a maximum of 2.5%. For roadways with design speeds of 50 mph or greater, superelevation of the roadway is acceptable and expected by motorists.

2. Intersection Alignment

The centerline of a street approaching another street from the opposite side should not be offset. If the offset cannot be avoided, the offset should be 150 feet or greater for local streets. The centerline of a local street approaching an arterial or collector street from the opposite side should not be offset unless such offset is 300 feet or greater.

Intersections should meet at a 90-degree angle. Under certain conditions, skewed intersection alignments may be necessary. Refer to the AASHTO Green Book for skewed intersection design.

3. Adding, Dropping, or Redirecting Lanes

a. Dropping or Redirecting Through Lanes:

When dropping a lane, the minimum taper ratio to be used should be determined by the following formula, or from the following Table 5C-2.01:

$L = WS$ for velocities of 45 mph or more

$L = \frac{WS^2}{60}$ for velocities of 40 mph or less.

L = Minimum length of taper.

S = Numerical value of posted speed limit or 85th percentile speed, whichever is higher.

W = Width of pavement to be dropped or redirection offset.

Preferably, taper ratios should be evenly divisible by five. Calculations that result in odd ratios should be rounded to an even increment of five. The table below utilizes the formulas to determine the appropriate taper ratio for dropping a 12 foot wide lane. The ratio remains constant for a given design speed while the length varies with the pavement width.

TABLE 5C-2.01
MINIMUM LENGTH AND TAPER RATIO FOR DROPPING 12' LANE

Design Speed (mph)	25	30	35	40	45	50	55	60
Taper Ratio	10:1	15:1	20:1	25:1	45:1	50:1	55:1	60:1
Length (ft)	120	180	240	300	540	600	660	720

The procedure for determining the minimum taper ratios for redirecting through lanes is the same as for lane drops, except for design speeds over 45 mph, the use of reverse curves rather than tapers is recommended.

b. Adding Through or Turn Lanes:

For design speeds of 45 mph or greater, a 15:1 lane taper should be used when adding a left or right turn lane. For design speeds less than 45 mph, a 10:1 taper may be used.

D. Vertical Alignment

1. Minimum Grades:

Flat and level grades on uncurbed pavements are preferred when the pavement is adequately crowned to drain the surface laterally. However, with curbed pavements, longitudinal grades must be provided to facilitate surface drainage. A typical minimum grade is 0.6%, but a grade of 0.5% may be used in isolated areas where the pavement is accurately crowned and supported on firm subgrade. The minimum allowance grade for bubbles and cul-de-sacs is 1%. Particular attention should be given to the design of storm water inlets and their spacing to keep the spread of water on the traveled way within tolerable limits. Roadside channels and median swales frequently require grades steeper than the roadway profile for adequate drainage.

2. Maximum Grades:

Grades for urban streets should be as level as practical, consistent with the surrounding terrain. The maximum design grades specified in Chapter 5 Tables should be used infrequently; in most cases grades should be less than the maximum design grade. Where sidewalks are located adjacent to a roadway, a maximum roadway grade of 5% is desirable. ADA requirements allow sidewalks adjacent to a roadway to match the running grade of the roadway, regardless of the resulting grade. However, sidewalk accessibility is greatly enhanced, especially over long distances, when grades are limited to 5% or less. It is recognized that meeting limitations will not be possible or practical in many situations; however, an attempt should be made to limit roadway grades to this level, especially in areas with high levels of anticipated pedestrian usage.

3. Maximum Grade Changes:

Except at intersections, the use of grade breaks, in lieu of vertical curves, is not encouraged. However, if a grade break is necessary and the algebraic difference in grade does not exceed 1%, the grade break will be considered by the Engineer.

4. Vertical Curves:

Vertical curves should be simple in application and should result in a design that is safe, comfortable in operation, pleasing in appearance, and adequate for drainage. The major control for safe operation on crest vertical curves is the provision of ample sight distances for the design speed. Minimum stopping sight distance should be provided in all cases. Wherever economically and physically feasible, more liberal stopping sight distances should be used. Furthermore additional sight distance should be provided at decision points.

For both sag and crest vertical curves with a low algebraic difference in grade, sight distance restrictions may not control the design of the curve. In these cases, rider comfort and curve appearance are the primary considerations for vertical curve design. Generally, vertical curves with a minimum length (in feet) equal to three times the design speed (in mph) are acceptable.

Drainage considerations also affect the design of vertical curves where cubs are utilized. Both crest and sag vertical curves that have a grade changes from positive to negative (or vice versa) contain a level area at some point along the curve. Generally, as long as a grade of 0.30% is provided within 50 feet of the level area, no drainage problems develop. This criterion corresponds to a K value of 167. K values greater than 167 may be utilized, but additional consideration should be given to drainage in these situations.

5. Intersection Grades:

The grade of the "through" street should take precedence at intersections. At intersections of roadways with the same typology, the more important roadway should have this precedence. Side streets are to be warped to match through streets with as short a transition as possible, which provides a smooth ride. Consideration must be given to minimize sheet flow of storm water across the intersection due to loss of crown on the side street. Carrying the crown of the side street into the through street is not allowed. In most cases the pavement cross-slope at the warped intersection should not exceed the grade of the through street. The maximum desirable grades of the through street at the intersection and the side street cross-slope should be 2%. The maximum desirable approach grade of the side street should not exceed 4% for a distance of 100 feet from the curb of the through street (which may require benching of a 2% section to accommodate a crosswalk), and a grade of 2% or less is desirable for ease of designing crosswalks.

Establishing intersection spot grades by matching “curb corners” of intersecting streets is not recommended since it may result in an undesirable travel path from the through street to the side street because of the resulting bump on the side street center line. At sidewalk curb ramps in intersections, the street grades may need to be warped at the curb line to ensure the resulting cross-slope at the bottom of the ramp does not exceed 2%. A detail of the jointing layout with staking elevations should be shown on the plans. ADA regulations set specific limits for crosswalk cross-slopes that directly impact street and intersection grades. ADA regulations limit the cross-slope to 2% (measured perpendicular to the direction of pedestrian travel) for crosswalks that cross a roadway with stop control (stop sign) at the intersection. For steep roadways without stop control, construction of a flattened "table" will be necessary to reduce the street grade to 2% or less at the location of the crosswalk. Crosswalk tables at these locations must utilize vertical curves, appropriate for the design speed, to avoid a sudden change in grade at the intersection that could cause vehicles to bottom out or lose control. For steep roadways with stop control, construction of a flattened "table" may utilize grade breaks or shortened vertical curves to reduce the street grade to 2% or less at the location of the crosswalk. A check should be made to verify that vehicles will not bottom out when traveling over the crosswalk table.

E. Pavement Crowns

The following typical pavement crowns are straight line cross-slope and are desirable sections.

1. Urban Roadways (Curb and Gutter):

For streets with three or fewer travel lanes, the pavement crown should be 2.5%. For streets with four or more travel lanes, the pavement crown for all inside lanes, including left turn lanes, should be 2.5%. In order to reduce stormwater spread, the pavement crown for the outside lanes can be increased to 3%. For all streets, auxiliary right turn lanes will have varying pavement crowns depending on the desired drainage pathway.

2. Rural Roadways:

For pavement crowns, a 2.5% cross-slope is normal with 4% shoulder slope. Iowa DOT Standard Road Plans should be checked for Federal Aid, Farm to Market, and Secondary Roads.

F. Lane Widths

Lane widths are specified in the design criteria tables. These lane widths may be adjusted to accommodate locations for heavy trucks, buses or other unusual conditions.

G. Two-way Left-turn Lanes (TWLTL)

Two-way left-turn lanes work well where design speeds are relatively low (25 to 50 mph) and there are no heavy concentrations of left turning traffic. The width of TWLTLs should be limited to the maximum turn lane widths specified in the design criteria tables to discourage left-turning motorists from pulling out into the TWLTL and stopping perpendicular to the direction of traffic, while they wait for oncoming traffic to clear.

H. Raised Median Width

The roadway width valued tabulated in the design criteria tables do not include median widths. Medians are encouraged and may take one of the following three forms:

- In a 2-lane Thoroughfare, a median of 6 feet (face to face) or wider can simply be inserted between the two Travel Lanes.

- In a 3-lane or 5-lane Thoroughfare, the Median can match the width of a center Turn Lane, and drop away where that lane occurs at corners. In this configuration, the Median shall begin and end with a semicircular shape, and the Transition Zone shall not be marked in any way, as turning drivers will know to merge left beginning when the Median ends.

- In a 3-lane or 5-lane Thoroughfare, a Median can exceed the width of a center Turn Lane by at least 6 feet, such that it narrows in order to include the Turn Lane at corners. In this condition, 3-Lane Thoroughfares shall not provide Bulb-Outs surrounding parking at corners.

It is desirable that center medians be planted either with shrubs or with Street Trees as space and driver sight lines permit. Planted medians must be carefully considered as they almost always require an agreement with the adjoining property owners to maintain the median plantings (particularly shrubs and flowering plants). In these cases, the designer should coordinate the agreement with the property owners and the City in conjunction with the development of planting plans. If there are Street Trees flanking the Thoroughfare, align median trees with them all the way to their ends. Where soil conditions permit, wide Center Medians may be used for storm water infiltration, requiring properly-graded roadways and an open or gapped inner-Curb detail.

Median widths are affected by sidewalk and crosswalk locations. Where a crosswalk cut through is present or proposed, medians (exclusive of any turn lanes) must be a minimum of 6 feet wide (face to face) to comply with ADA regulations. These regulations require the placement of a 2 foot wide strip of detectable warnings at the curb line on both sides of the median. The detectable warnings must be separated by a minimum 2 foot strip without detectable warnings. Where the median has no curb, the detectable warnings must be placed along the edge of the roadway. At locations where a raised median is stopped short of the crosswalk, the 6 foot raised median and associated detectable warnings are not required, and a minimum 4 foot raised median (face to face) section may be used.

I. Bridges

Bridge width is measured as the clear width between curbs or railings. Minimum bridge width is based upon the width of the traveled way (lane widths) plus 4 feet clearance on each side; but no less than the curb-face to curb-face width of the approaching roadway. Sidewalks should extend across the bridge on both sides. Under unusual circumstances, a sidewalk on only one side of the bridge may be permitted upon concurrence of the Jurisdictional Engineer. Minimum clearances on sidewalks to bridge walls and railings is 2’.

For existing bridges, a structural analysis should be conducted. The existing bridge should be able to accommodate legal loads. Bridge guardrail should be upgraded if necessary.

J. Clear Zone

Horizontal clearance is measured from the back of curb in urban sections and from the edge of travel lane in rural sections.

The desired width is dependent upon the street typology and speeds. For higher speeds (Posted 40 mph and above), the latest AASHTO Roadside Design guide shall be used to verify the horizontal clearance dimensions. For lower speeds, refer to the values in the design criteria tables. Parking lanes and bicycle lanes may be included as part of the clear zone. However a minimum clear zone behind the back of curb of 3’ should be provided regardless of the thoroughfare composition.

K. Object Setback

Object setback is similar to clear zone except this is the minimum area behind the curb where no objects are allowed to create operational space for snow storage, opening car doors, accommodating mailboxes, etc. The Object setback is 1.5’ from back of curb. Exceptions include mailboxes constructed and installed according to US Postal Service regulations, traffic control signs constructed per the MUTCD, and other items on a case-by-case basis as approved by the Jurisdictional Engineer.

L. Border Area

Border area is the space between the back of curb and the right-of-way available for sidewalks, plantings/landscaping, utilities, and buffer space. The minimum right-of-way widths shown in the design criteria tables provide for the minimum border areas of 17’ – 20’ to accommodate all of the above elements. Wider border areas are encouraged up to 30’ to allow for double row tree plantings or other public use space.

M. Curbs

1. **Curb Offset:** The curb offset is measured from the back of curb to the edge of the lane. The curb offset widths of 1.5’, minimum, and 2’ desirable do not necessarily indicate the width of the curb and gutter or the location of a longitudinal joint; however, the width of the curb and gutter can affect the required width of the curb offset. The presence of a longitudinal joint near the curb (gutterline jointing) can be a limiting factor for usable lane width as some drivers are uncomfortable driving on or near the joint line. This is especially true for HMA roadways with PCC curb and gutter. For pavements with a longitudinal joint line near the gutter, the curb offset

should be equal to or greater than the width of the curb and gutter section. In addition, grates and special shaping for curb intakes and depressions for open-throat intakes should be located within the curb offset width and should not encroach into the lane.

2. **Curb and Gutter:** Typically, a curb and gutter cross-section should consists of a 6 inch high, 6 inch wide curb with a concrete gutter section. If the design speed is 40 mph or below, an 8 inch curb may be used for certain arterial and collector streets. For design speeds greater than 40 mph, a 1 foot wide, 6 inch high sloped curb with a minimum 2 foot gutter offset should be used. Other shoulder and offset requirements may be needed for high speed design, particularly on State and Federal jurisdiction roadways. Refer to Iowa DOT and FHWA design standards for those situations.

N. Parking Lanes

On street parking shall be included at locations meeting the parking criteria in this Chapter 5. Angled parking can be head in or back in as appropriate. Where space is available, consideration should be given to providing a 3' wide park assist lane between the parking lane and the travel way to provide space so car doors can be opened and vehicles can enter or depart with a higher degree of safety and less delay. Bike lanes can serve this function as well. Parking assist lanes also narrow the feel of the travel and slow traffic.

O. Cul-de-sacs

A dead end should have a cul-de-sac constructed at the closed-end for turn-around. The maximum length of thoroughfare leading to a cul-de-sac should be 300 feet. The turning area shall be circular (not hammerhead) and have a radius appropriate to the type of vehicles expected. Commercial cul-de-sacs should have a minimum radius of 50 feet with an encompassing right-of-way radius of 65 feet. Center radii for residential cul-de-sacs and right-of-way should be 44 feet and 60 feet, respectively.

P. Shoulder Width

Shoulders accommodate stopped vehicles, emergency use, bicycling space, and provide lateral support of the subbase and pavement. Where no curb and gutter is constructed a soil, granular, or paved shoulder will be provided.

Desirably, a vehicle stopped on the shoulder of a speed-flow thoroughfare should clear the pavement edge by 2 feet. This preference has led to the adoption of 10 feet as the desirable shoulder width that should be provided along high volume facilities. In difficult terrain and on free-flow/slow-flow, or low volume highways, usable shoulders of this width is not practical or desirable. Where roadside barriers, walls, or other vertical elements are used, the graded shoulder should be wide enough that these vertical elements can be offset a minimum of 2 feet from the outer edge of the usable shoulder. It may be necessary to provide a graded shoulder wider than used elsewhere on the curved section of a roadway or to provide lateral support for guardrail posts and/or clear space for lateral dynamic deflection required by the particular barrier in use.

On low volume roads, roadside barriers may be placed at the outer edge of the shoulder; however, a minimum of 4 feet should be provided from the traveled way to the barrier.

Q. Intersection Radii

Minimum curb return radii are shown below. Where truck traffic is present, and on bus routes, return radii should be provided according to the current AASHTO Green Book turning templates. When parking lanes and/or bike lanes are present, the curb return radii may be reduced, per below, to reflect the effective space available for right turning movements as long as the turning template path of the selected design vehicle still meets the minimum radii listed below. In no case shall the curb return radii be reduced to less than 15'.

1. Minimum radii are as follows if any of the these conditions are met:
   a. For all streets 32' wide face of curb to face of curb and narrower
   b. Absence of offsets beyond the minimum gutter width from the travel lanes such as parking lanes, bike lanes and additional gutter width.

Radii to Back of Curb	**Roadway Classification, Intersecting Street**			
Roadway Classification	**Arterial**	**Collector**	**Local (Commercial /Industrial)**	**Local (Residential)**
Arterial	Special*	35'	35'	35'
Collector	35'	30'	30'	25'
Local (Commercial/Industrial)	35'	30'	25'	25'
Local (Residential)	35'	25'	25'	25'

*Special design required. Use turning templates.

2. Minimum radii with parking and/or bike lanes (i.e., effect radius):

   a. Meet the minimum effective radii listed in the table in Section 1 above with the back of curb radius being reduced by the distance beyond the minimum gutter width.

   b. Example 1: Intersection of two commercial collector streets, 40' wide face to face:
   From Table 5c-1.01: Gutter = 1.5', Parking Lane 9'
   Additional width beyond gutter = 9' – 1.5' = 7.5'
   From table above, curb return radius = 30'. Radius can be reduced as:
   30' – 7.5' – 0.5' (curb width) = 22'

   c. Example 2: Same situation as example 1, but includes an additional 8' wide bike lane (5' lane plus 3' buffer) between the parking lane and the travel lane.

The minimum back of curb radius would be 30’ – 7.5’ – 0.5’ - 8’ = 14’ < 15’ Minimum. Therefore the back of curb radius is set to the minimum allowable 15’.

R. Pavement Thickness

Refer to the Table 5C-1.01 in this chapter for minimum pavement thicknesses.