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THE CITY OF COLUMBUS
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DEPARTMENT OF PUBLIC SERVICE

DESIGN MEMO 7.05

To:	Designers, Contractors, and City Departments
Date:	January 1, 2025
Subject:	Intersecting Roadways – Pavement Transition
Category:	Streets

Table of Contents

1 Purpose

The purpose of this design memo is to establish guidelines for the design of pavement transition for intersecting roadways. This memo includes guidance on profile grades and cross slope transitions through intersections. In addition, examples are provided that illustrate how this guidance has been utilized in various scenarios.

2 Applicability

Until further notice, this direction will be used for scoping, design and review within the City of Columbus jurisdiction. The guidance provided in this memo is applicable to all projects including both capital improvement projects and private development projects, except where noted.

While an alley crossing is not always considered an intersection (see definition of an intersection below), the guidance of this design memo should still be applied at alleys to the greatest degree practical, as a best practice.

3 Definitions

Definitions of key terms in this memo are provided below. Additional definitions are provided in the City of Columbus Design Memo 1.00: Introduction.

Superelevation

Per the Federal Highway Administration (FHWA), superelevation “is the rotation of the pavement on the approach to and through a horizontal curve. Superelevation is intended to assist the driver by counteracting the lateral acceleration produced by tracking the curve.” This concept is used to keep drivers from sliding on horizontal curves, but it can also be applied to safely transition roadway cross-slopes in a smooth manner.

Cross Slope

Pursuant to the Ohio Department of Transportations (ODOT) Location and Design Manual, Volume 1, Cross Slope is defined as, “the rate of change of elevation along a straight line from one point in cross section to another”.

Intersection

As defined by AASHTO, “an intersection is defined as the general area where two or more highways join or cross, including the roadway and roadside facilities for traffic movements within the area.”

Ohio Revised Code, Section 4511.01 defines an intersection as:

(1) The area embraced within the prolongation or connection of the lateral curb lines, or, if none, the lateral boundary lines of the roadways of two highways that join one another at, or approximately at, right angles, or the area within which vehicles traveling upon different highways that join at any other angle might come into conflict. The junction of an alley or driveway with a roadway or highway does not constitute an intersection unless the roadway or highway at the junction is controlled by a traffic control device.

(2) If a highway includes two roadways that are thirty feet or more apart, then every crossing of each roadway of such divided highway by an intersecting highway constitutes a separate intersection. If both

intersecting highways include two roadways thirty feet or more apart, then every crossing of any two roadways of such highways constitutes a separate intersection.

(3) At a location controlled by a traffic control signal, regardless of the distance between the separate intersections as described in division (2) of this section:

> (a) If a stop line, yield line, or crosswalk has not been designated on the roadway within the median between the separate intersections, the two intersections and the roadway and median constitute one intersection.
>
> (b) Where a stop line, yield line, or crosswalk line is designated on the roadway on the intersection approach, the area within the crosswalk and any area beyond the designated stop line or yield line constitute part of the intersection.
>
> (c) Where a crosswalk is designated on a roadway on the departure from the intersection, the intersection includes the area that extends to the far side of the crosswalk.

4 References

4.1 ODOT Location and Design Manual

The ODOT Location and Design Manual, Volume 1 gives guidance on how to design and execute a superelevation transition. Per the manual: “The superelevation runoff (“Lr”) is the length required to raise the “outside” edge of traveled way from a “half flat” section to a fully superelevated section”. The calculation for the superelevation runoff can be used to estimate an appropriate minimum length for a cross-slope transition. Figure 202-4 of the Location and Design Manual, Volume 1 defines the variables and provides the equation for this calculation. These variables and the corresponding formula generate the calculation for the minimum pavement transition length that is used in intersection design. The formula and variables used are shown below:

$$L_r = \frac{(w \times n_1)\ e_d}{\Delta}\ (b_w) \times 100$$

L_r = minimum length of superelevation runoff, ft
L_t = minimum length of tangent runout, ft
Δ = maximum relative gradient, percent
n_1 = number of lanes rotated
w = width of one traffic lane, ft (typically 12 ft)
e_d = design superelevation rate

Values for b_w and Δ can be looked-up on Figure 202-4.

Figure 203-2 of the ODOT Location and Design Manual, Volume 1 defines several terms regarding vertical profile design. Using design speed as the primary variable, the Figure outlines the maximum grade change that can be used without installing a vertical curve. Designers should use this methodology as a guide when designing vertical profiles through intersections.

4.2 ADA Guidance

Columbus follows federal guidance regarding ADA policy. Federal rights-of-way ADA policy (PROWAG) outlines the acceptable cross-slopes and longitudinal grades within crosswalks. Design for intersecting roadways shall consider these guidelines, as they will put some constraints on what can be designed.

When designing an intersection, it is necessary to keep an ADA compliant Pedestrian Access Route (PAR) throughout pedestrian crosswalks. Any roadway longitudinal slope within the PAR should remain below the federal maximum permitted cross-slope and any roadway cross-slope should do the same.

Per the Federal Public Right of Way Accessibility Guidelines (PROWAG), the following maximum cross slopes are permitted at crosswalks:

R302.5.2.1 Crosswalk at yield or stop sign controlled approach – 2.08% maximum cross-slope
R302.5.2.2 Crosswalk at uncontrolled approach – 5.00% maximum cross-slope
R302.5.2.3 Crosswalk at traffic signal-controlled approach or pedestrian hybrid beacon-controlled approach – 5.00% maximum cross-slope.
R302.5.2.4 Mid-block crosswalk or roundabout crosswalks – shall not exceed the street grade.

5 Design Guidance

5.1 Signalized vs. Un-signalized Intersections

When designing the grading at intersecting roadways, it is important to consider the traffic conditions. An intersection with a stop condition will have significantly less design constraints, as traffic comes to a complete stop before proceeding through the intersection at a slower speed. A similar condition is present for a Yield intersection, although to a lesser extent. A lower design speed may be used for pavement transitions in intersections with this design condition. Figure 401-2 in the ODOT Location and Design Manual, Volume 1 provides guidance for a stop-condition intersection. Please refer to Section 401.4.3 and Figure 401-2 for further detail.

Pavement transitions for through vehicle movements at signalized intersections shall be developed using the roadway design speed for each approach. Refer to Section 401.4.4 and Figure 401-4 for signalized intersections. The transition from the cross-slope of the approach to the profile of the intersecting roadway shall be developed using the criteria outlined in outlined in Section 5.3 and 5.4.

5.2 Curbed vs. Un-curbed Roadways

An important consideration for the design of a roadway intersection is the presence of curb, or lack there-of. For adequate drainage, it is critical for curbed roadways to have a slope along the face of curb. Flat areas adjacent to radii can cause ponding; this is hazardous for driver safety as well as the maintenance of the roadway. Curbed pavements have a preferred minimum slope of 0.75% and an absolute minimum slope of 0.50% along the radius of the intersection.

Un-curbed pavements do not have the same drainage issues as curbed pavements. Un-curbed pavements do not trap water in the roadway. For un-curbed roadways, there are no minimum slopes required along the radii as long as adequate drainage is provided in the cross-slope direction.

Another consideration for radial slopes is ADA compliance and the presence of crosswalks. Where crosswalks are located along the radius of an intersection, ADA compliance shall be met as outlined within this document. This applies to both curbed and un-curbed roadways.

5.3 Intersecting Roadway Profile Grades

When designing a roadway profile, it is crucial to consider intersecting roadways. The profile grades should match at the point of intersection. Any grade breaks along a roadway profile shall follow Figure 203-2 in the ODOT Location and Design Manual, Volume 1. This figure gives details regarding maximum grade changes along roadway profiles without requiring a vertical curve, using design speed as the dependent variable. Roadway profiles also shall abide by ADA guidelines within the established crosswalks at each intersection.

Slopes in excess of 5% should be avoided at all roadway intersections at the centerline. For signalized intersections, the point of intersection should not be used as the high or low point of a vertical curve as this can create very flat slopes near the center of the intersection. However, the point of intersection may be used as a high point grade break if the maximum change in vertical alignment is not exceeded and no vertical curve is required.

For curbed streets, low points or sags along the centerline profile should be avoided within the center of the intersection (area inlaid within the curbs). Conversely, if it is necessary to have a low point or sag on the profile, it should fall within the limits of the curb radii so curb inlets can be installed.

The grading of the entire intersection should be derived from the centerline profile of the road and shall determine the required pavement transitions.

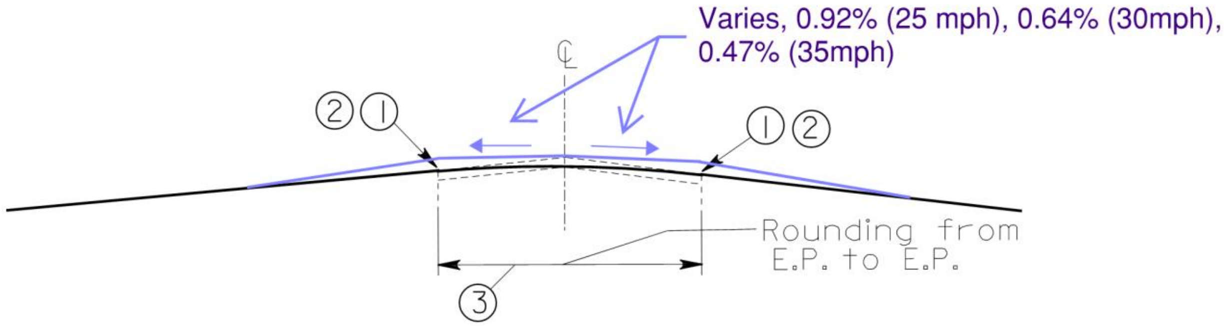
5.3.1 Crossroad Profile at Stop Controlled Intersections

Profile grades within the intersection area for stop conditions are shown in Figures 401-2 and 401-3 of the ODOT Location and Design Manual, Volume 1. The grade outside the intersection area is controlled by the design speed of the crossroad. Normal design practices can be used outside the intersection area with the only restriction on the profile being the sight distance required.

Grade breaks are permitted at the mainline edge of traveled way for a stop condition as discussed in Note 3 of Figures 401-2. If these grade breaks are exceeded, they should be treated according to Note 3 on Figure 401-3. Several examples are shown on Figure 401-3 of the use of grade breaks or short vertical curves adjacent to the mainline edge of traveled way.

5.3.2 Crossroad Profile at Signalized Intersections

Signalized intersections require a more sophisticated crossroad profile. Whenever possible, profiles through the intersection area of a signalized intersection should be designed to meet the design speed of the crossroad. Figure 401-4 shows three examples of crossroad profiles at intersections. On Examples A and B (Figure 401-4), the mainline cross slopes will need to be adjusted to match the crossroad profile within the intersection area. Grade breaks shown on Examples A and C should be in accordance with Section 203.3.2. Since the grade break across a normal crowned pavement is 3.2 percent, it should be noted that the crown must be flattened (See Example C). Alternately, when the crossroad design speed is 35 mph or less, the grade break across the crown can be reduced by reducing the pavement cross slope from the crown (See Example C, Modified, below). This will allow vehicles on the crossroad to pass through the intersection on a green signal safely without significantly adjusting their speed. The sight distance requirements within the intersection area are also applicable for signalized intersections.



5.4 Designing Cross Slope Transitions

The approaching legs of an intersection need to be transitioned to meet the cross-slope of an intersection street.

Stop-Controlled

Where the minor road is stop controlled, the profile and cross-slope of the major road will be maintained through the intersection. The cross-slope of the stop-controlled leg(s) will be transitioned to match the major-road profile.

Signalized Intersections

At a signalized or a potentially signalized intersection, the cross-slopes of all legs of the intersection will be transitioned to match the profile of the intersecting street.

Transition Rate

When one or both intersection roadways are transitioned, the designer must determine the length and rate of transition from the normal crown section to the modified section. The transition should be designed to meet the general principles of superelevation transition applicable to the roadway.

Pavement cross-slope transition shall conform to the requirements outlined in the ODOT Location and Design Manual, Volume 1, Section 4.1. The minimum transition length between two cross-slopes will be defined as "Lr" in Figure 202-4.

The calculated distance represents the minimum length that should be used to transition between two intersecting cross-slopes. This transition length may be increased if applicable and shall be applied at a consistent rate of change. It is recommended that intersection cross-slope transitions should extended at a minimum to the Point of Tangency (PT) of the curb or curve radii.

5.5 Plan Standards

Grading within an intersection, shall be detailed on intersection detail sheets. Intersection grading details should be set at a 1”=10’ scale and curb ramp grading details set at a 1”=5’ unless otherwise approved by the City Project Manager. Spot elevations are required every 25’ along the centerline for each intersecting roadway. Additionally, all grade breaks and PAR routes shall be labeled accordingly with corresponding spot elevations and slope labels.

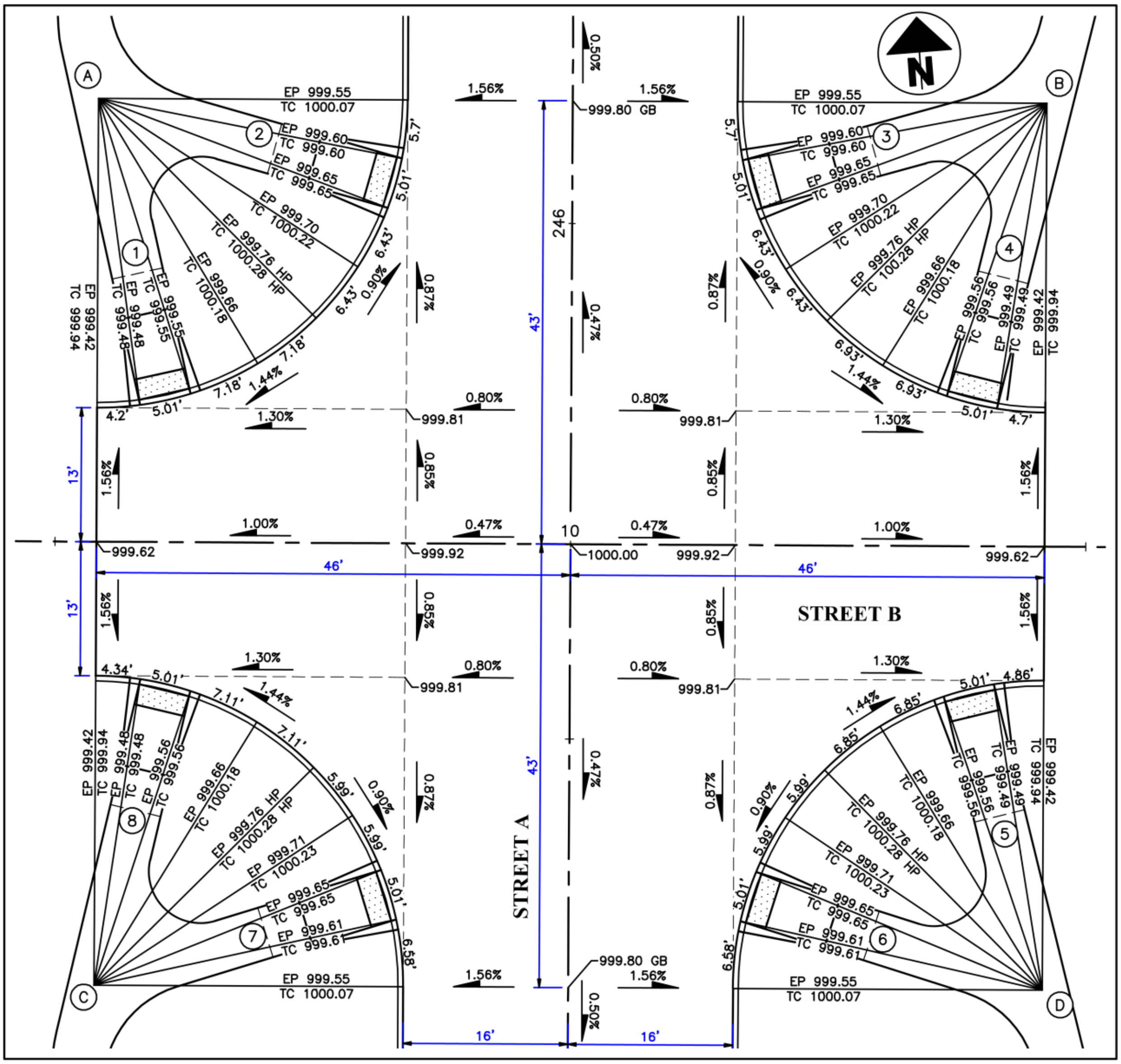
Pavement transitions should be labeled to show a uniform slope transition from the beginning of the transition to the end. There needs to be enough information given for the Contractor to be able to build the pavement transition; this can be covered with labels on the intersection grading details or a separate superelevation table if needed due to increased complexity. The information provided on the intersection detail sheets shall fully convey the intent of the design to the Contractor, without requiring any supplemental information such as office calculations, 3D grading models, etc. Additionally, areas of the intersection between the given grade/elevation callouts are assumed to transition smoothly from one elevation or grade to the next. Therefore, all grade breaks, critical elevations, and critical slope transitions shall be identified.

The Columbus CIP Sample Plans provide an example illustrating format and content for intersection grading details. Please note that the sample plan is illustrating plan formatting only; and should not be referenced for design guidance.

6 Design Example/Case Studies

The scenarios outlined below have been furnished to provide an example and case studies on general format, content and presentation requirements for various conditions. These examples should not be considered collectively exhaustive. Intersection details shall be tailored to meet the unique constraints of the project while conforming to the design requirements and boundaries outlined herein.

6.1 Example: Standard Perpendicular Intersection



Both roads are crowned at the centerline, and both roads have a design speed of 35 miles-per-hour. The intersection is signalized.

1. Looking at this intersection, the cross-slopes of Street B will need to be transitioned to match the profile grade of the intersecting Street A.
2. The cross-slope on each side of this leg is 1.56% toward the edge of pavement; this slope needs to transition to a 0.47% cross-slope. The 0.47% cross slope was chosen to provide a grade break across the pavement crown of 0.94%, which is less than the maximum grade change of 0.95% for a design speed of 35mph from Figure 203-2.
3. Each side of the crown contains one lane of pavement, 13 feet wide.
4. This road is both signalized and curbed. Both of these details will play a factor in the grading design of this intersection.
5. Using this information and ODOT Figure 202-4, we can define our variables and calculate our minimum transition length for each side (north and south) of the western leg of the intersection.

<u>North/South Side of intersection (Street B):</u>

n_1 = 1 lane (Street B has two 13' lanes)

b_w = 1.00

w = 13'

e_d = (0.0156 - 0.0047) = 0.0109

Δ = 0.62 (for 35 mph)

L_r = (((13' x 1) x 0.0109) ÷ 0.62) x 1.00 x 100 = 22.85' MINIMUM length for transition

<u>East/West Side of Intersection (Street A):</u>

n_1 = 1.5 lanes (Street A is a three-lane section, so 1.5 lanes are being transitioned)

b_w = 0.83

w = 10.67' (Street A has a total width of 32', divided by three lanes, equals a 10.67' wide lane)

e_d = (0.0156 - 0.0047) = 0.0109

Δ = 0.62 (for 35 mph)

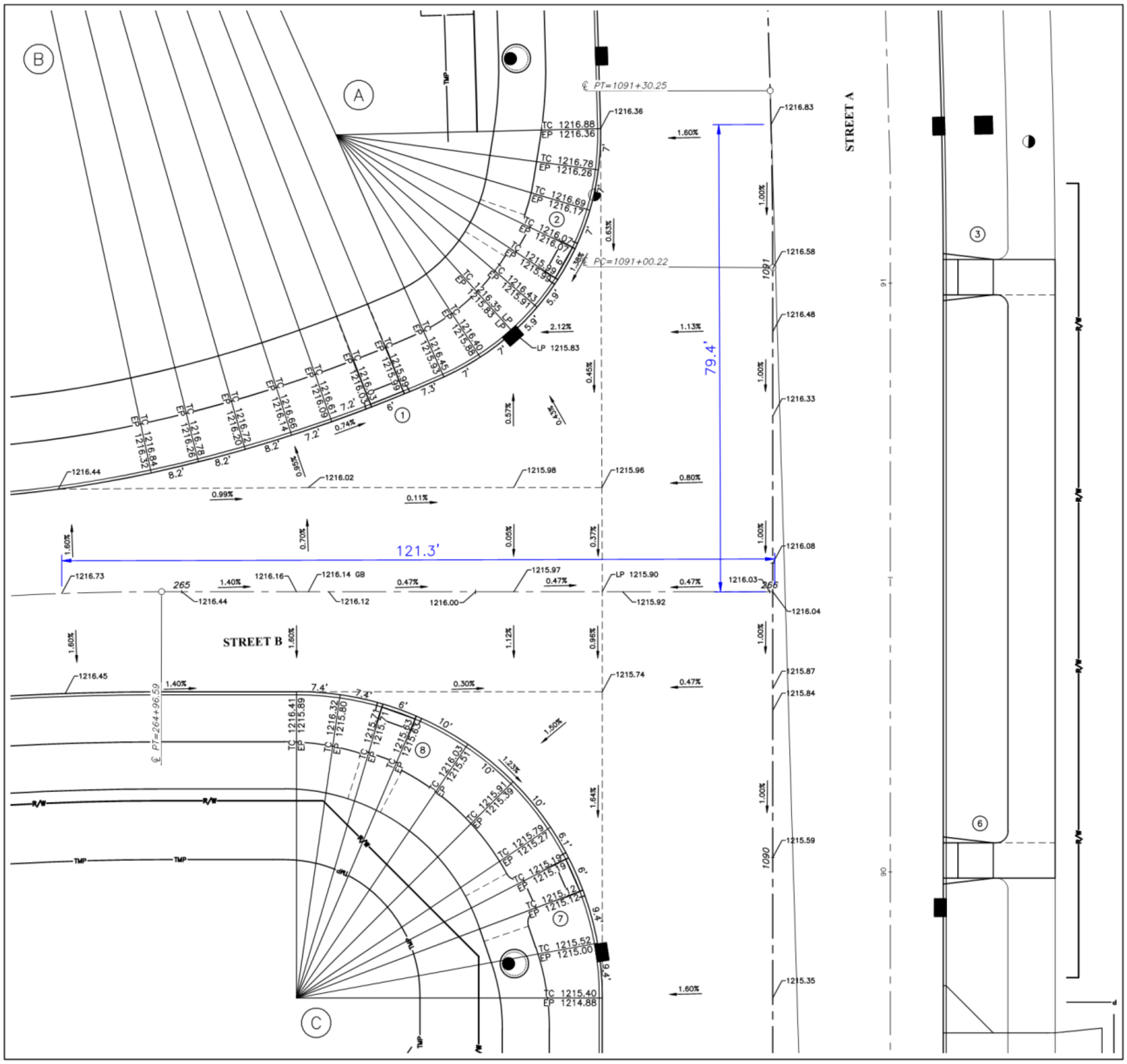
L_r = (((10.67' x 1.5) x 0.0109) ÷ 0.62) x 0.83 x 100 = 23.35' MINIMUM length for transition

Using these calculations, transitions were designed for cross-slopes of the four legs of this intersection to transition to the intersecting profile grade. The highest minimum length calculated was 23.35 feet. Using this calculation and the conditions of the intersection, a transition length of 46' in the east/west direction and 43' in the north/south direction was used for transitions on both sides of the pavement crown. The full limits of the intersection (46' east/west and 43' north/south) were used to provide a smooth transition. The smooth transition of slopes is shown in the intersection detail shown above.

6.2 Case Studies

The following four (4) case studies are examples of constructed intersections. The purpose of these case studies are to illustrate how site specific constraints impact design. These examples should <u>not</u> be used as design guidance or best practices. Rather, they are intended to show examples of how engineering judgement was applied, given site specific constraints.

6.2.1 Case Study 1: Tee Intersection

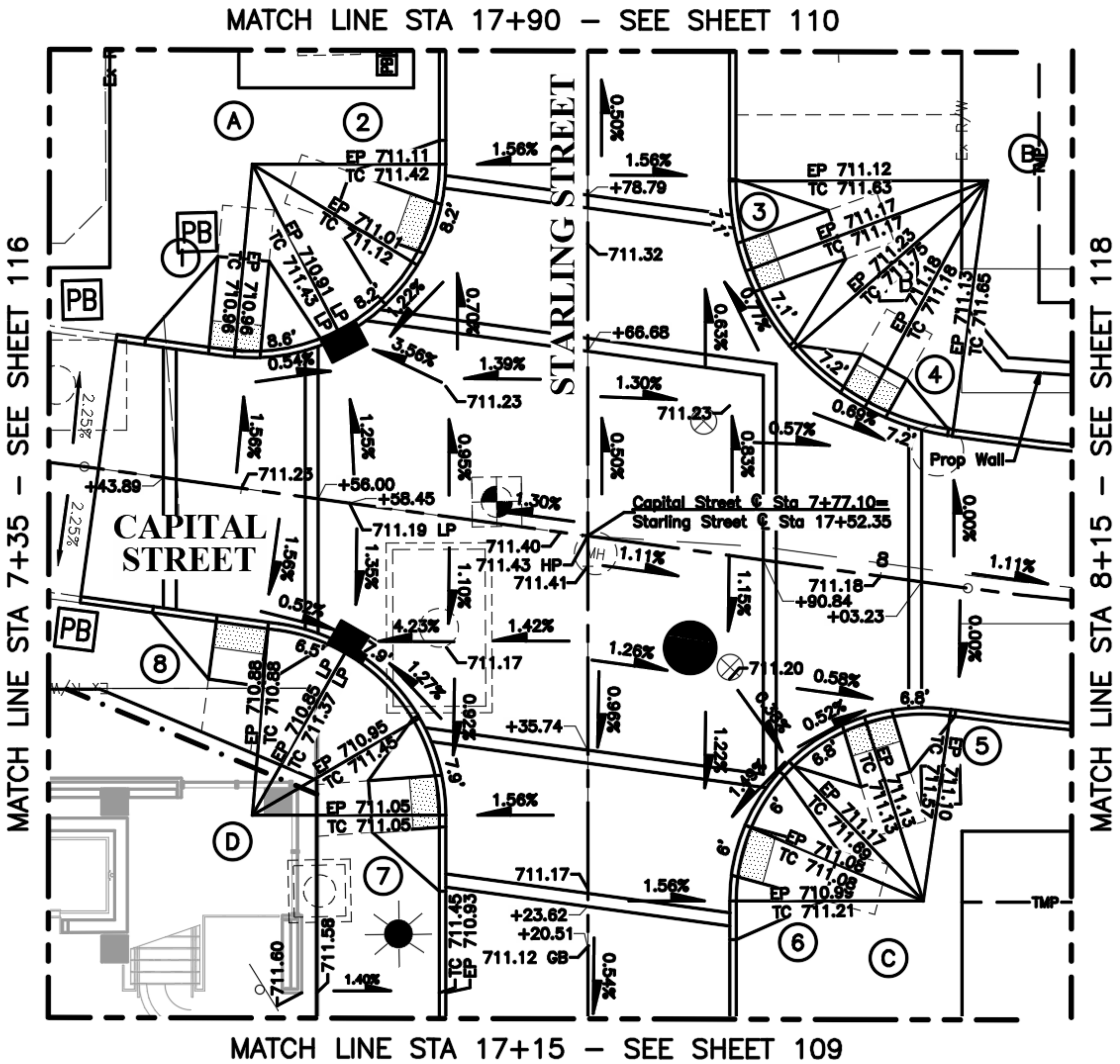


<u>General Intersection Characteristics</u>

- Curb roadway.
- Design for future signalization and the extension of Street B.
- Street A: 45 mph design speed. Street B: 35 mph design speed.

This example transitions from a 1.60% towards the curbline to 1.00% in the opposite direction on the North side of Street B. The 1.00% in the opposite direction matches the profile grade at the centerline of the intersecting Street A. The western side of Street A transitions from a 1.60% cross-slope towards the curbline to the intersecting profile grade of 0.47% at Street B. The lengths shown for the transition are conservative; the calculated minimum lengths are much lower. To accomplish a well graded intersection, more length was used for the cross-slope transition.

6.2.2 Case Study 2: Low Point in Intersection



General Intersection Characteristics

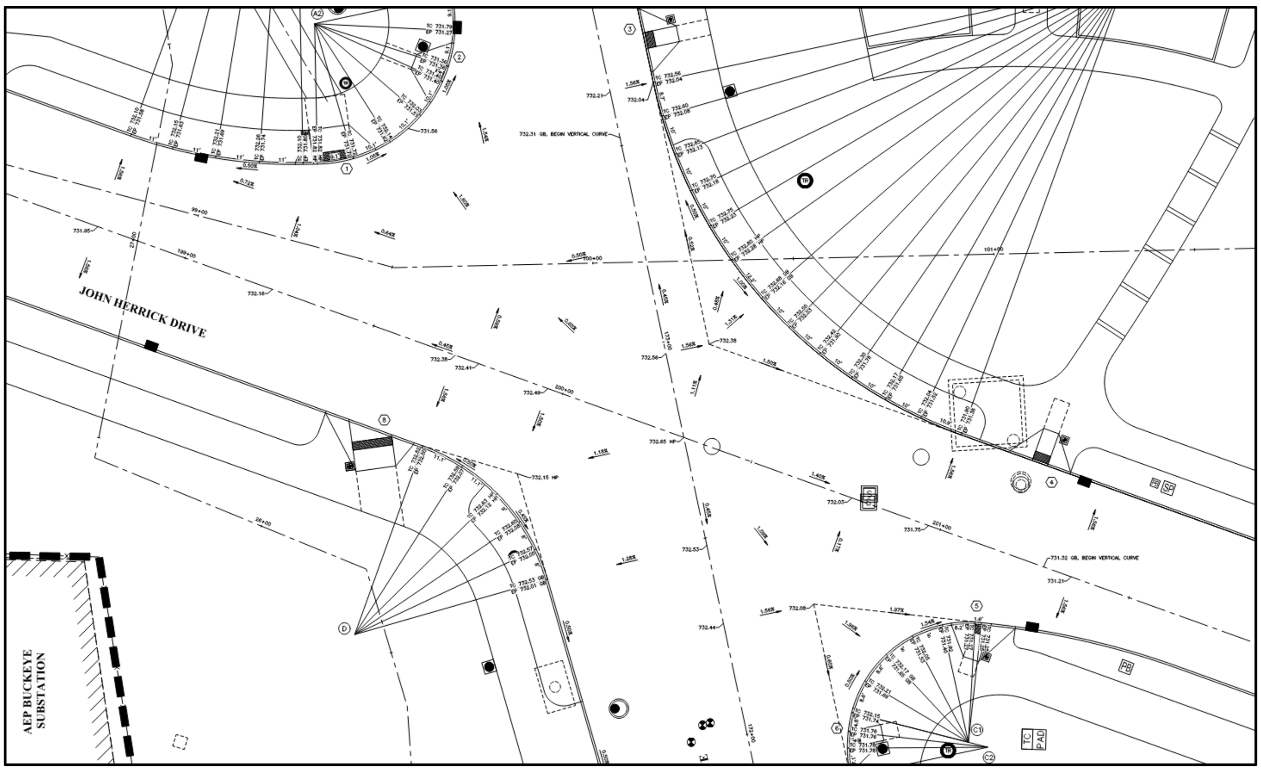
- Curb roadway.
- Stop sign controlled on east-west street (Capital Street). North-south street (Starling Street) is uncontrolled.
- Capital Street is an alley.
- Both streets have a 25 mph design speed.

The intent of this example is to convey the level of complexity resulting from existing and proposed constraints in dense urban and downtown environments. This is a crowded intersection with multiple design constraints that impacted the design of the intersection grading; if not for these constraints, a typical stop controlled intersection design would have maintained the cross slope of Starling Street. The western portion of the intersection tied into existing cross-slopes, which were not ADA compliant. This had to be transitioned to be ADA compliant before reaching the PAR of the crosswalk.

The southwest corner of this intersection contained a proposed building. The grades that were needed to tie-into this building at the entryway created unique grading challenges. To make these grades work, the radial grades of the west leg of the intersection required a low point with curb inlets. This solution helped alleviate some of the complicated grading challenges at intersecting roadways.

The eastern leg of this intersection included permeable pavement in the design. For permeable pavement to reach maximum efficiency, the roadway cross-slope should be 0%. The cross-slopes of the eastern leg were transitioned to match the intersecting roadway profile grade, as shown above.

6.2.3 Case Study 3: Skewed Intersection



<u>General Intersection Characteristics</u>

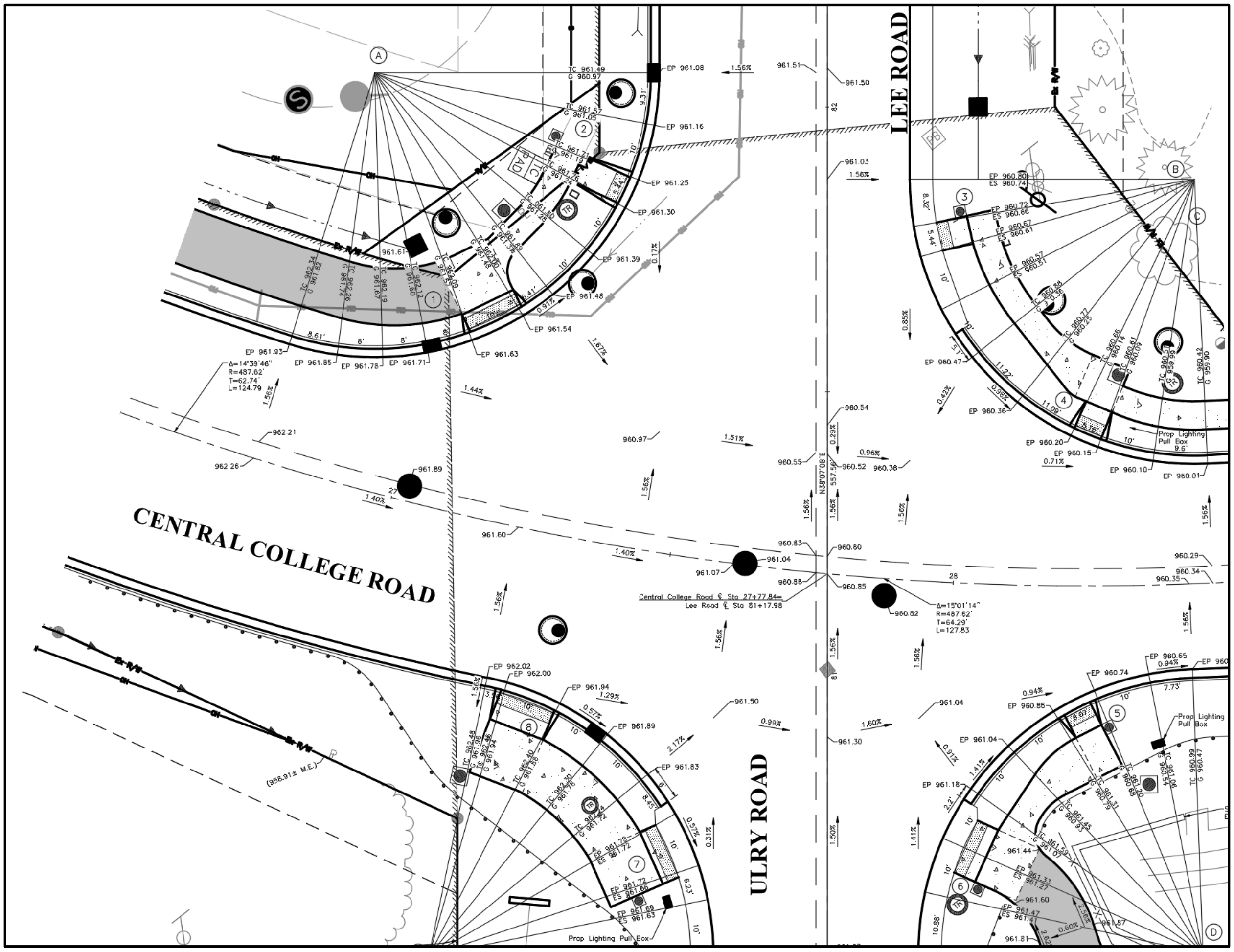
- Curb roadway.
- Signalized intersection.
- Both streets have a 20 mph design speed.

Skewed intersections create unique challenges for grading. Generally, a skewed intersection will introduce more pavement, particularly in the acute intersection corners, when compared to a similar perpendicular intersection. Vehicles also require additional room to make turns around tighter acutely skewed corners.

With more pavement to grade, some complicated grading scenarios may be encountered. If the intersecting roadway profiles have a relatively flat slope, it can be difficult to produce adequate drainage away from the center of the intersection. The solution used in the intersection above was to place inlets before entering the intersection; any drainage flowing towards the intersection would be picked up before reaching the flat areas. Other unique grading solutions were used, including pavement transitions and varying radial slopes.

This is one situation where intersecting roadway profile grades and pavement transitions should be considered to create a sufficient solution.

6.2.4 Case Study 4: Superelevation through Intersection



<u>General Intersection Characteristics</u>

- East/west roadway (Central College Road) is curbed. North/south roadway (Lee/Ulry Road) is a mix of curbed and un-curbed.
- Signalized intersection.
- A design variance was approved for profile of Lee/Ulry Road to lower the design speed through the intersection.

- Central College east leg: 35 mph design speed. Central College west leg: 50 mph design speed. Lee Road: 45 mph design speed. Ulry Road: 50 mph design speed.

The intersection shown above shows a fully superelevated lane that is maintained throughout the intersection. This intersection required a complete pavement transition prior to reaching the portion of the intersection that is detailed on this view. In this case, the pavement transition needed to accomplish this need to be detailed on a separate pavement grading detail. Please refer to the Columbus CIP Sample Plans for details regarding pavement grading details.

Whenever an intersection requires this method of superelevation, design speed should be considered for through traffic. Driver safety is of the highest priority and transitions should be made within the superelevation guidance provided in the ODOT Location and Design Manual, Volume 1. This type of intersection is still required to comply with all ADA requirements that have been discussed. Any transitions that are needed to accomplish this superelevation are to be made using the guidance outlined in this document.