Geometric Review and Design (GRAD)

Intersections
Learning Objectives

- Understand the different types of intersections
- Understand the different contributors to a well-designed intersection
- Recognize the impacts intersection design has on other disciplines
Intersections

- Sect 401
- Defined as the general area where two or more roadways join or cross
- Often the focus of business and community activity and the place where systems users share the same travel space
- Should consider the needs of all users
- Location where most traffic conflicts occur
Intersection Control

- Sect 401.2
- Type of Intersection Control directly affects the geometric design.
- Types of intersection control:
  - Stop
  - Yield
  - Signal
Intersection Control

- Roundabouts and Restricted Crossing U-Turns design guidance has been recently added to the L&D Manual
- These two intersection controls will not be discussed in this module - look for a future module on these topics
Crossroad Alignment

- Sect 401.3
- Intersection angles of 70 to 90 degrees are to be provided on all new or relocated highways
- An angle of 60 degrees may be satisfactory if:
  - Intersection is signalized
  - Intersection is skewed such that a driver stopped on the side road has the acute angle on their left side (vision not blocked by their own vehicle)
Crossroad Alignment
### Alignment

- **Horizontal deflection through the intersection**
  - Maximum centerline deflection without a horizontal curve
  - Applies to the through movement in an intersection

### Table: Maximum Centerline Deflection Without Horizontal Curve

<table>
<thead>
<tr>
<th>DESIGN SPEED (mph)</th>
<th>MAX. DEFLECTION *</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW SPEED</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>5° 30'</td>
</tr>
<tr>
<td>30</td>
<td>3° 45'</td>
</tr>
<tr>
<td>35</td>
<td>2° 45'</td>
</tr>
<tr>
<td>40</td>
<td>2° 05'</td>
</tr>
<tr>
<td>45</td>
<td>1° 40'</td>
</tr>
<tr>
<td>HIGH SPEED</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>1° 05'</td>
</tr>
<tr>
<td>55</td>
<td>1° 00'</td>
</tr>
<tr>
<td>60</td>
<td>0° 55'</td>
</tr>
<tr>
<td>65</td>
<td>0° 50'</td>
</tr>
<tr>
<td>70</td>
<td>0° 45'</td>
</tr>
<tr>
<td>75</td>
<td>0° 45'</td>
</tr>
</tbody>
</table>

* ROUNDED TO NEAREST 5°

Based on the Allowable Pavement Transition formulae (301.1.4):
- High Speed: \( \tan \Delta = 1.0/V \)
- Low Speed: \( \tan \Delta = 60/V^2 \)

Where:
- \( V \) = Design Speed
- \( \Delta \) = Deflection Angle

Note:
The recommended minimum distances between consecutive horizontal deflections is:
- High Speed – 200'
- Low Speed – 100'
Alignment

Explanation of Figure 401-1 Typical Crossroad Relocation

1. Curve - This portion of the crossroad can occur by itself at "T" type or three-legged intersections. If possible, the radius of this curve should be commensurate with the design speed of the crossroad. Often, the length of the required profile controls the work length. The horizontal curvature is then chosen so it can be accomplished within this work length. Regardless of the length of the profile adjustment, it is desirable to provide at least a 230 foot radius for this curve. When a 230 foot radius incurs high costs, it is permissible to reduce this radius to a minimum of 150 ft.

2. Tangent and Approach Radial - The crossroad in this area should have a tangent alignment. For the condition shown, the alignment between the radius returns is tangent from one side of the road to the other. However, at some intersections with a minor through movement (for example, crossroad intersections of standard diamond ramps) it may be desirable to provide different intersection angles on each side of the through road. For approach radials, see discussion in Section 401.5.

3. Curve - The statements in (1) above also apply to this curve. With the reverse curve condition shown, the radius will often not exceed 250 ft. because flatter curves make the relocation extraordinarily long.

4. Tangent - This tangent should be approximately 150 ft. in length for 30 or 40 mph design speeds on the existing road, and approximately 250 ft. for 50 or 60 mph design speeds. These lengths are generous enough to allow reasonable superelevation transitions between the reverse curves. In general, it is usually not desirable to make this tangent any longer than required. If a longer tangent can be used, the curvature or intersection angle can be improved and these two design items are more important.

5. Curve - This curve should be much flatter than the other two curves. It should be capable of being driven at the normal design speed of the existing crossroad.
Alignment
Alignment
Alignment
Crossroad Profile

- Sect 401.4
- Portion of the intersection located within 60 feet of the mainline edge of traveled way is considered the “intersection area”
- The pavement surface, including radius returns and pavement markings, should be visible to drivers within the “intersection area”.

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Crossroad Profile

- Stop Controlled Intersections
  - Refer to Figure 401-3 for profile guidance when through road is superelevated
Crossroad Profile

- **Signalized Intersections**
  - Where possible, profiles through the intersection area should be designed to meet the design speed of the crossroad
  - Sight distance requirements of Section 401.4.1 within the “intersection area” are applicable for signalized intersections
Crossroad Profile

COMMERCIAL ROAD

A = +7.22%
B = +7.90%
C = +7.02%
D = +0.50%
E = +1.60%

P.V.I. STA 10+28.70
ELEV = 609.79
10.00 VE
K = 2
SSD = 79'

P.V.I. STA 11+35.00
ELEV = 611.92
10.00 VE
K = 27
SSD = 79'
Va = 25 MPH

MATCH PROPOSED
ELEV = +6.52

MATCH EXISTING
ELEV = -7.90

PROPOSED PROFILE
COMMERCIAL ROAD

MATCHED PROFILE
COMMERCIAL ROAD

PC Sta. 13+62.99

STA. 15+00.00 EAST 9TH STREET = STA. 10+00.00 COMMERCIAL ROAD

B EAST 9TH STREET

STA. EOU.

540 560 580 600 620 640 660 680 700

10 11 12 13 14 15
Crossroad Profile

- Intersection Detail Sheets
  - Edge of Traveled Way profiles
  - May require warping the pavement
  - Provide positive drainage
  - Often an iterative process
Approach Radii

- Sect 401.5
- Rural

- Minimum 35 ft approach radius - primarily at minor intersecting roads
- Preferably 50 ft approach radius
- If design must routinely accommodate semi-trailer trucks, look at larger radius, radius with a taper, or a three-center curve
Approach Radii

- Urban
  - Corner radii should consider:
    - Available right-of-way
    - Intersection angle
    - Pedestrian traffic
    - Approach width
    - Number of lanes
Approach Radii

- Urban
  - Corner radii guidance:
    - 15-25 ft - passenger vehicles; adequate at minor cross streets with little trucks or major intersections where there are parking lanes
    - 25 ft radius or greater - minor intersections on new or reconstructed projects where space permits
    - 30 ft radius or greater - major cross street intersections where feasible
    - 40 ft radius or more, three-centered curves, simple curves with tapers - intersections used frequently by buses or larger trucks
  - Use Engineering Judgement - consider ALL users to minimize impacts to them
Approach Radii

- Curbed to Uncurbed Transitions
  - Uncurbed mainline roadway to a curbed approach roadway
  - Refer to Section 305.4 for curb height transition guidance

See Section 305.4 For Curb Height Transitions
Approach Radii

- Curbed to Uncurbed Transitions
  - Curbed mainline roadway to an uncurbed approach roadway
  - Option 1
    - Extend curb around radius return; transition width over radius return to shoulder width
  - Option 2
    - Extend shoulder around radius return; transition width using 4:1 taper prior to radius return
- Refer to Section 305.4 for curb height transition guidance
Approach Lanes

- Sect 401.6
- Approach lanes to consider:
  - Left Turn Lanes
  - Dual Left Turn Lanes
  - Right Turn Lanes
  - Dual Right Turn Lanes
  - Two-Way Left Turn Lanes (TWLTL)
Left Turn Lanes

- Sect 401.6.1
- Best if placed opposite each other on opposing approaches to enhance sight distance
- Several options for how to develop left turn lanes based on available width
  - Widen on both sides
  - Widen solely on one side
  - Open within the median
  - Offset left turn lane in wide medians to obtain adequate sight distance
Left Turn Lanes

- Develop turn lanes using several types of tapers:
  - Approach taper - directs through traffic to the right
    - High Speed: \( L = WS \)
    - Low Speed: \( L = WS^2 / 60 \)
  - Departure taper - directs through traffic to the left; length should not be less than approach taper length
  - Diverging taper - used at the beginning of the turn lane; recommended length is 50 feet
Left Turn Lanes

- Establish the length of storage length needed using capacity analysis
  - Figures 401-9 and 401-10 aid in determining the required lengths of left turn lanes at intersections

- Check the length of storage available in adjacent through lane(s) to assure left turn isn’t blocked by through lanes

- Set the location of the stop bar using autoturn for intersection turning movements prior to finalizing turn lane placement
Left Turn Lanes

- Width of left turn lane should desirably be the same as the normal lane widths for the facility
- Minimum width of 11 feet may be used in moderate and high-speed areas
- 10 feet wide left turn lanes may be provided in low-speed areas
- Additional width should be provided whenever the lane is adjacent to a curbed median
Offset Left Turn Lanes

- In locations with wide medians, it is often necessary to offset the left turn lane to line up opposite the left turn lane on the opposite approach to provide adequate sight distance.
Offset Left Turn Lanes

- **Positive Offset**
  - Vehicles left of center of the opposing turning vehicle; can see around them
  - Used to ensure path overlap with the opposing turning vehicle doesn’t exist
  - Can be permissive left turns at signals

- **Negative Offset**
  - Vehicles right of center of the opposing turning vehicle; can’t see around them
  - Should be protected left turns at signals
Dual Left Turn Lanes

- Should be considered at any signalized intersection with left turn demands of 300 vph or more
- Confirm need with signalized intersection capacity analysis
- Determine design vehicles
- Ensure there are no conflicts with turning paths
- Check all turning paths using truck turning templates; allow 2 feet between tire path and edge of each lane
Dual Left Turn Lanes

Design Speed | L1 | L2
---|---|---
40 mph | 125’ | 75’
45 mph | 175’ | 125’
50 mph | 225’ | 145’
55 mph | 285’ | 165’
60 mph | 345’ | 185’
65 mph | 405’ | 205’

- Use Figure 401-10 to determine storage length. For offset left turn lanes, minimum storage length equals 8 x offset + 50’.

- Taper is used when dual left turn lanes are offset.

If opposite approach has one left turn lane, these lanes should line up.

Blends created by excess pavement are normally identified using pavement marking.
Right Turn Lanes

- Width of right turn lane should desirably be the same as the normal lane widths for the facility.
- 10 feet wide right turn lanes may be provided in low-speed areas.
- Additional width should be provided whenever the lane is adjacent to a curb.
- Recommended maximum length at signalized intersections is 800 feet.
- Minimum length is 100 feet.
Dual Right Turn Lanes

- When justified, they are usually desired at an intersection involving either an exit ramp or a one-way street
- Require larger intersection radius, usually 75 feet or larger, and a throat width comparable to a double left turn to accommodate truck tracking
Turn Lane Warrants

- Sect 401.6
- Intersection capacity procedures of the current edition of the HCM should be used to determine the number and use of left turn lanes
- Exclusive right turn lanes are less critical in terms of safety than left turn lanes but do provide a means for safe deceleration
Two-Way Left Turn Lanes (TWLTL)

- Sect 402
- TWLTL should be considered whenever actual or potential midblock conflicts occur
- Closely-spaced driveways, strip commercial development, or multiple-unit residential land use along a corridor can trigger need for TWLTL
- Widths are preferably the same as through lane widths. 10-foot wide lane may be used in restricted areas. Wider than 14 feet is discouraged
Design Considerations

- Path Overlap
  - Allow opposing left turns to be accommodated at the same time; same signal phase.
  - Watch geometry of dual turn lanes.
  - Use truck turning templates
  - Establish stop bar locations that are not in conflict with turning vehicles; this is needed to size turn lane lengths
Design Considerations

- Path Overlap
  - Make sure that the most appropriate design vehicle(s) is being used
  - Review encroachment into adjacent or opposing lanes for both the approaches and the departures

<table>
<thead>
<tr>
<th>Degree of Encroachment</th>
<th>Departure</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Encroachment</td>
<td>1 No Encroachment</td>
</tr>
<tr>
<td></td>
<td>2 Encroachment into the adjacent lane (same direction)</td>
</tr>
<tr>
<td></td>
<td>3 Encroachment into the opposing lane</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approach</th>
<th>Departure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A1</td>
</tr>
<tr>
<td></td>
<td>A2</td>
</tr>
<tr>
<td></td>
<td>A3</td>
</tr>
<tr>
<td>B</td>
<td>B1</td>
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<tr>
<td></td>
<td>C3</td>
</tr>
</tbody>
</table>
Design Considerations

- Path Overlap
Design Considerations

- Path Overlap
Design Considerations

- Islands
  - Sect 401.7
  - Islands are defined areas between traffic lanes used for control of vehicle movement.
  - Separate conflicts
  - Control the angle of conflicts
  - Indicate proper use of intersection
  - Provide for pedestrian refuge and traffic control devices.
Design Considerations

- Pedestrian Accommodations
  - Sect 401.8
  - Provide corner radius that is appropriate for both vehicles and pedestrians
  - Consider two distinct radii
    - Radius of street corner
    - Effective turning radius of selected design vehicle

Curb Return Radius = 15’
Effective Radius = 68’

Permit vehicle to turn into adjacent lane to keep smaller radius
Design Considerations

- Pedestrian Accommodations
  Parking lane locations:
  - 20 feet in advance of crossing location when speeds are $\leq 25$ mph
  - 30 feet in advance of crossing location when speeds are between 26 mph and 35 mph
- Curb Extensions
Design Considerations

- Curb Ramps
  - Sect 306.3
  - General Requirements
    - Minimum / preferred landing / turning space width
    - Cross slopes & running slopes
    - Vertical deflection
    - Detectable warning mat
    - Curb ramp surfaces

No ADA curb ramp; how will he navigate the curb?
Design Considerations

- Curb Ramp Types
  - Perpendicular
  - Parallel
  - Blended Transition
  - Single Sided Parallel
Design Considerations

- Pedestrian Accommodations
  - Curb ramp alignment for ramp pairs
  - Ramp location with respect to the radius return
  - Work closely with traffic designers to ensure push buttons are located appropriately from the curb ramp
Design Considerations

- Pedestrian Accommodations
  - Accommodating ramps in retrofit cases.
Design Considerations

- Drainage
  - Sect 401.4.2
  - Ensure positive drainage to avoid trapping water, especially in front of a curb ramp
  - Warping pavement within the intersection area can introduce high/low points that will impact drainage
  - Watch small-radius curb returns - catch basin castings do not curve
Design Considerations

- **Pedestrian Accommodations**
  - Desirably, median islands should be at least 6 feet wide
  - Minimum median width of 8 feet to accommodate bicycles, wheelchairs, scooters, and groups of pedestrians
  - Minimum width of 8 feet on high-speed roadways
  - Crossing width minimum, or Pedestrian Access Route (PAR), should be 5’
Driveway Design

- Rural Residential Drives and Field Drives
  - Sect 803.2
  - Normally conform to Type 1 design shown in Standard Construction Drawing BP-4.1
  - New drives should intersect the highway at an angle between 70° and 90°
  - Existing drives - existing width is normally maintained unless less than 12 feet; then it should be widened to provide a 12-foot throat width
  - New drives - 12 feet for a single drive; combined drive between two properties shouldn’t exceed 24 feet wide
Driveway Design

- Vertical Geometry
  - Sect 804
  - Uncurbed roadways
    - Drive profiles shall slope down and away from the edge of traveled way at the same slope as the graded shoulder
    - Vertical curves to be placed outside of the graded shoulder width
    - Vertical curve lengths should be 10 feet to 20 feet, depending on grade differential
    - Max. grades should not exceed 10%, with 8% max. considered preferred
Driveway Design

- Urban Residential Drives
  - Sect 803.3
  - Type 1 Drives - circular radius returns
    - Radius should normally be 25 feet; may be increased on field drives to improve operations for farm equipment
    - Desirable minimum radii is 15 feet
  - Type 2 Drives - chamfered radius returns
  - Curbed drives abutting uncurbed highways - curb no closer than 8 feet from the mainline edge of traveled way
Driveway Design

- Vertical Geometry
  - Curbed roadways
  
  - Drive profile criteria established based on a specific design vehicle shown in Figure 803-2 with springs completely compressed
  
  - If conditions don’t allow a drive design to meet the criteria established in 804.2, use a template of the design vehicle
Driveway Design

- Pedestrian Accommodations
  - For residential drives, try to avoid the “roller coaster” effect where the sidewalk dips up and down to accommodate the drive
  - Adjust the drive apron from the roadway to the walk to meet the walk; keep the walk at a constant elevation/grade
Driveway Design

- Standard Commercial Drives
  - Sect 803.5
- Radii
  - 15 foot minimum when highway is curbed
  - 25 foot minimum when highway is uncurbed
  - Use design vehicle turning template to establish max radii
- Width - 35 foot maximum
Driveway Design

▪ Vertical Geometry
  ▪ Commercial Drives - curbed roadways
Driveway Design

- Pedestrian Accommodations
  - For commercial drives or when the walk is at the back of curb, may introduce curb ramps to transition the walk down to the drive apron elevation
  - Use engineering judgement - sometimes the ramps are not provided and the apron is adjusted to meet the sidewalk elevation; determine vehicle usage and clearance requirements
Module Review

- Key Terms
  - Intersection Angle
  - Approach Radii/Radius Return
  - Approach/Departure Taper
  - Diverging Taper
  - TWLTL
  - Intersection Area
  - Path Overlap
  - Islands
  - Type 1/Type 2 Drives