KCI TECHNOLOGIES
ENGINEERS | PLANNERS | SCIENTISTS | CONSTRUCTION MANAGERS

Project: Wood Ave HOP 22209756
By: ZMK **Date:**
Ckd: **Date:**
Sheet ______ **of** ______
Subject: Proposed SE Calcs for 8% Max from NC

SR 2017 (Hackett Ave) Enter

Starting Sta.	207+36.00	Starting Superelevation	0.0200	(2% NC)	**Design Speed = 35 mph**	
Ending Sta.	209+57.70	Ending Superelevation	-0.0800	(8% Max SE)	n(# of lanes rotated)=	1.5
					w(lane width)=	11
Transition Length	221.70	Change in Superelevation	-0.1000		b_w(adjust factor)=	0.83
					Max Rel Gradient[1]=	0.62
		Relative Gradient	**0.62**	ok		

Lr = 177.00
1/3 Lr = 59.00

T = 220.89
ok

PC STA	208+98.70
FULL SUP	209+57.70

Notes:

1 - 2018 AASHTO Green Book, Chapter 3

SR 2017 (Hackett Ave) Exit

Starting Sta.	209+82.86	Starting Superelevation	-0.0800	(2% NC)	**Design Speed = 35 mph**	
Ending Sta.	212+04.00	Ending Superelevation	0.0200	(8% Max SE)	n(# of lanes rotated)=	1.5
					w(lane width)=	11
Transition Length	221.14	Change in Superelevation	0.1000		b_w(adjust factor)=	0.83
					Max Rel Gradient[1]=	0.62
		Relative Gradient	**0.62**	ok		

Lr = 177.00
1/3 Lr = 59.00

T = 220.89
ok

FULL SUP	209+82.86
PT STA	210+41.86

Notes:

1 - 2018 AASHTO Green Book, Chapter 3

NOTE: Proposed superelevation calculations are based on an 8% Design SE from NC.

- The design vehicle occupies a greater width because the rear wheels generally track inside the front wheels (off-tracking) in negotiating curves.
- Drivers may experience difficulty in steering vehicles in the center of the lane.

The needed traveled way width has several variables including track width for passing or meeting vehicles, lateral vehicle clearance, width of inner lane vehicle front overhang, and a width allowance for the difficulty of driving a curve as discussed in the Green Book, Section 3.3.10, *Traveled-Way Widening of Horizontal Curves*.

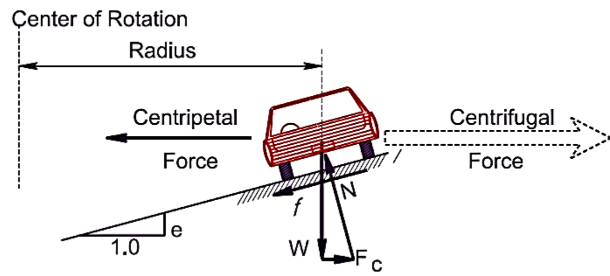
Widening should transition gradually on curve approaches to ensure a reasonably smooth alignment of the traveled way edge and to fit the turning path of the design vehicle as it enters and leaves the curve.

- On simple circular (non-spiraled) curves, widening should be applied on the inside edge of the traveled way only. On spiraled curves, widening may be applied on the inside edge or divided equally on either side of the lane centerline. The final marked centerline, and desirably any central longitudinal joint, should be placed midway between the edges of the widened traveled way.
- Curve widening should transition gradually over a length sufficient to make the whole of the traveled way fully usable. Preferably, widening should transition over the superelevation runoff length, but shorter lengths are sometimes used. Changes in width should be affected over a distance of 100 to 200 ft.
- The edge of the traveled way through the widening transition should be a smooth, graceful curve and a tangent transition edge should be avoided. The transition ends should avoid an angular break at the pavement edge.
- On highway alignments without spirals, smooth and fitting alignment results from attaining widening with one-half to two-thirds of the transition length along the tangent and the balance along the curve. The inside edge of the traveled way may be designed as a modified spiral, with control points determined by the width/length ratio of a triangular wedge, by calculated values based on a parabolic or cubic curve, or by a larger radius (compound) curve. On highway alignments with spiral curves, the increase in width is usually distributed along the length of the spiral.

Traveled way widening on an open roadway curve shall occur over the length of superelevation transition as shown in **Exhibit 3.3.1**.

3.3 – Superelevation

When a vehicle moves in a circular path, it undergoes a centripetal acceleration that acts toward the center of curvature. This acceleration is sustained by a component of the vehicle's weight related to the roadway superelevation, by the side friction developed between the vehicle's tires and the pavement surface, or by a combination of the two. The factor, known as superelevation, consists of tilting the roadway to provide safe and continuous vehicle operation.



A vehicle traveling at a constant speed on a curve superelevated for that specific speed, the side friction value is zero and the centripetal acceleration is sustained by the vehicle's weight resulting in no steering effort on the part of the vehicle operator. The curves on a given facility are designed for a certain running speed and vehicles traveling at that speed should be able to negotiate the turns with ease. Vehicles, however, travel at a wide range of speeds and therefore the drivers must exert themselves to successfully negotiate these curves. They are aided by side friction on the tires. From the minimum radius equation in the Green Book, Section 3.3.3, *Design Considerations*, it is evident that superelevation is based on design speed; therefore, the classes of highways shall be superelevated according to their speed rather than using a superelevation for a single radius for all design speeds.

3.3.1 – Maximum Superelevation

The maximum rate of superelevation shall be limited to 6.0% in urban areas, and 8.0% in rural areas. In densely populated urban areas where traffic congestion and extensive land development restrict design speeds to 45 mph or less, PennDOT recommends the use of low-speed urban design which is discussed in Section 3.3.2.

These maximum superelevation rates are based on consideration of climate, terrain, type of area (urban or rural), and frequency of very slow-moving vehicles. In urban areas where population densities are much higher than in rural areas, there is greater potential for traffic congestion. During cold weather months when traffic congestion coincides with snow and ice conditions, travel speeds are reduced, and there is a greater potential for stopped or slow-moving vehicles to slide across superelevated pavement. In rural areas there is less potential for traffic congestion, but the possibility of sliding due to cold weather conditions still exists.

Similarly, either a low maximum rate of superelevation or no superelevation is often recommended in intersection areas or where the posted speed limit (or running speeds) is less than 25 mph due to turning and crossing movements, warning devices and signals. In these areas, it may be difficult to warp crossing pavements for drainage without providing negative superelevation for some turning movements.

3.3.2 – Low-Speed Urban Superelevation Design

On low-speed (40 mph or less) urban streets where design speeds are relatively low and variable, designing superelevation based on the maximum rate for urban streets of 6% is often impractical. PennDOT recognizes these limitations and that drivers on low-speed urban streets are generally more accepting of the slight discomfort caused by lateral acceleration on horizontal curves. PennDOT provides the following options for reducing the rate of superelevation on low-speed urban streets:

1) **The Green Book, Section 3.3.5, *Design Superelevation Tables*.** This approach limits the maximum superelevation rate to 4% and refers to Green Book, Table 3-8, *Minimum Radii for Design Superelevation Rates, Design Speeds, and* e_{max} *= 4%*. Green Book, Figure 3-3, "Side Friction Factors for Streets and Highways", shows the recommended side friction factors for low-speed streets and highways. These recommended side friction factors provide a reasonable margin of safety at low speeds and lead to somewhat lower superelevation rates as compared to the high-speed friction factors. The side friction factors vary with design speed from 0.38 at 10 mph to 0.15 at 45 mph. Based on the maximum allowable side friction factors in Green Book, Figure 3-4, *Side Friction Factors Assumed for Design*, Green Book, Table 3-8, gives the minimum radii for the maximum superelevation rate of 4.0%.
2) **The Green Book, Section, 3.3.6, *Design for Low-Speed Urban Streets*.** This approach is recommended for the design of horizontal curves where, through conditioning, drivers have developed a higher threshold of discomfort. Under this method, it is assumed that none of the lateral force is counteracted by superelevation, provided the side friction factor is less than the specified maximum for the radius of the curve and the design speed. Refer to Green Book, Table 3-13, *Minimum Radii and Superelevation for Low-Speed Streets in Urban Areas*.

3.3.3 – Design Superelevation Tables

Refer to the Green Book, Section 3.3.5, *Design Superelevation Tables*. When using these tables for a given radius, interpolation is not necessary because the design superelevation rate should be determined from a radius equal to, or slightly smaller than, the radius provided in the Table. The result is a superelevation rate that is rounded up to the nearest 0.2%.

The Green Book, Section 10.9.6.2, *General Ramp Design Considerations*, provides guidelines for the design of superelevation and cross slope on ramps. Guidelines for the development of superelevation at free-flow ramp terminals are found in Green Book, Section 10.9.6.2.14, *Superelevation and Cross Slope*.

3.3.4 – Length of Superelevation Transition

When a vehicle enters or leaves a horizontal curve, it generally follows a suitable transition path within the limits of normal lane width. However, combinations of high speed and sharp curvature lead to longer transition paths, which can result in shifts in lateral position and encroachment on adjoining lanes. As discussed in Section 3.3.4.b, for comfort and safety, incorporation of a transition curve (a flatter circular curve in low-speed streets or ramp roadways with expectant varying curvatures, or spiral curve in higher speed roadways) should be provided. The transition curve is between the tangent and a sharper circular curve. It could also be between circular curves of substantially different radii. Transition curves may be appropriate to make it easier for

Table 3-10. Minimum Radii for Design Superelevation Rates, Design Speeds, and e_{max} = 8%

U.S. Customary														
e (%)	V_d = 15 mph	V_d = 20 mph	V_d = 25 mph	V_d = 30 mph	V_d = 35 mph	V_d = 40 mph	V_d = 45 mph	V_d = 50 mph	V_d = 55 mph	V_d = 60 mph	V_d = 65 mph	V_d = 70 mph	V_d = 75 mph	V_d = 80 mph
	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)	R (ft)
NC	932	1640	2370	3240	4260	5410	6710	8150	9720	11500	12900	14500	16100	17800
RC	676	1190	1720	2370	3120	3970	4930	5990	7150	8440	9510	10700	12000	13300
2.2	605	1070	1550	2130	2800	3570	4440	5400	6450	7620	8600	9660	10800	12000
2.4	546	959	1400	1930	2540	3240	4030	4910	5870	6930	7830	8810	9850	11000
2.6	496	872	1280	1760	2320	2960	3690	4490	5370	6350	7180	8090	9050	10100
2.8	453	796	1170	1610	2130	2720	3390	4130	4950	5850	6630	7470	8370	9340
3.0	415	730	1070	1480	1960	2510	3130	3820	4580	5420	6140	6930	7780	8700
3.2	382	672	985	1370	1820	2330	2900	3550	4250	5040	5720	6460	7260	8130
3.4	352	620	911	1270	1690	2170	2700	3300	3970	4700	5350	6050	6800	7620
3.6	324	572	845	1180	1570	2020	2520	3090	3710	4400	5010	5680	6400	7180
3.8	300	530	784	1100	1470	1890	2360	2890	3480	4140	4710	5350	6030	6780
4.0	277	490	729	1030	1370	1770	2220	2720	3270	3890	4450	5050	5710	6420
4.2	255	453	678	955	1280	1660	2080	2560	3080	3670	4200	4780	5410	6090
4.4	235	418	630	893	1200	1560	1960	2410	2910	3470	3980	4540	5140	5800
4.6	215	384	585	834	1130	1470	1850	2280	2750	3290	3770	4310	4890	5530
4.8	193	349	542	779	1060	1390	1750	2160	2610	3120	3590	4100	4670	5280
5.0	172	314	499	727	991	1310	1650	2040	2470	2960	3410	3910	4460	5050
5.2	154	284	457	676	929	1230	1560	1930	2350	2820	3250	3740	4260	4840
5.4	139	258	420	627	870	1160	1480	1830	2230	2680	3110	3570	4090	4640
5.6	126	236	387	582	813	1090	1390	1740	2120	2550	2970	3420	3920	4460
5.8	115	216	358	542	761	1030	1320	1650	2010	2430	2840	3280	3760	4290
6.0	105	199	332	506	713	965	1250	1560	1920	2320	2710	3150	3620	4140
6.2	97	184	308	472	669	909	1180	1480	1820	2210	2600	3020	3480	3990
6.4	89	170	287	442	628	857	1110	1400	1730	2110	2490	2910	3360	3850
6.6	82	157	267	413	590	808	1050	1330	1650	2010	2380	2790	3240	3720
6.8	76	146	248	386	553	761	990	1260	1560	1910	2280	2690	3120	3600
7.0	70	135	231	360	518	716	933	1190	1480	1820	2180	2580	3010	3480
7.2	64	125	214	336	485	672	878	1120	1400	1720	2070	2470	2900	3370
7.4	59	115	198	312	451	628	822	1060	1320	1630	1970	2350	2780	3250
7.6	54	105	182	287	417	583	765	980	1230	1530	1850	2230	2650	3120
7.8	48	94	164	261	380	533	701	901	1140	1410	1720	2090	2500	2970
8.0	38	76	134	214	314	444	587	758	960	1200	1480	1810	2210	2670

superelevation rate in excess of 2.0 percent, superelevation should be applied in accordance with Tables 3-8 through 3-12.

3.3.6 Design for Low-Speed Streets in Urban Areas

On low-speed streets in urban areas where speed is relatively low and variable, typically in the urban and urban core contexts, the use of superelevation for horizontal curves can be minimized. Where side friction demand exceeds the assumed available side friction factor for the design speed, superelevation, within the range from the normal cross slope to maximum superelevation, is provided.

3.3.6.1 Side Friction Factors

Figure 3-4 shows the recommended side friction factors for low-speed streets and highways as a dashed line. These recommended side friction factors provide a reasonable margin of safety at low speeds and lead to somewhat lower superelevation rates as compared to the high-speed friction factors. The side friction factors vary with the design speed from 0.38 at 10 mph [0.40 at 15 km/h] to 0.15 at 45 mph [0.15 at 70 km/h]. A research report *(44)* confirms the appropriateness of these design values.

3.3.6.2 Superelevation

Although superelevation is beneficial for traffic operations, various factors often combine to make its use impractical on low-speed streets in urban areas. These factors include:

- wide pavement areas;
- the need to meet the grade of adjacent property;
- surface drainage considerations;
- the desire to maintain low-speed operation; and
- frequency of intersecting cross streets, alleys, and driveways.

Therefore, horizontal curves on low-speed streets in urban areas are frequently designed without superelevation, sustaining the lateral force solely with side friction. For traffic traveling along curves to the left, the normal cross slope is an adverse or negative superelevation, but with flat curves the resultant friction needed to sustain the lateral force, even given the negative superelevation, is small.

Where superelevation will be applied to low-speed streets in urban areas, Method 2 is recommended for the design of horizontal curves where, through conditioning, drivers have developed a higher threshold of discomfort. By this method, none of the lateral force is counteracted by superelevation so long as the side friction factor is less than the specified maximum assumed for design for the radius of the curve and the design speed. For sharper curves, f remains at the maximum and e is used in direct proportion to the continued increase in curvature until e reaches

4.2.1.a – Reconstruction No Change In Road Type (NoCIRT) Criteria

If established performance measures are met, including a safety evaluation that shows no crash clusters or other multiple safety concerns related to the roadway geometry, then the design criteria for Reconstruction NoCIRT follows the criteria outlined in **Exhibit 4.2.2** and **Exhibit 4.2.4**. The outcome of the safety evaluation may indicate potential changes to the horizontal and vertical alignment, lane and shoulder widths, cross slopes, and clear zone. Projects with significant changes that result in a change in roadway type must follow design criteria in Chapter 3.

Since the roadway pavement is determined to be reconstructed (full depth, rubblized, crack and seat) down to the subgrade, most likely due to failing pavement, each component of the design criteria should be compared to New Construction criteria. Several questions should be asked, in regards to the existing and/or predicted future performance measures:

1) Is there substantial crash frequency and severity concerns pertaining to existing conditions?
2) Will improving the feature improve safety?
3) Are there any traffic operational issues?

For example, to analyze the cross section:

1) Is there substantial crash frequency and/or severity concerns pertaining to the cross section?
2) Will bike and pedestrian accommodations require widening of the lane and shoulder? Or will accommodations be accomplished by road diet?
3) Is there expected traffic growth thereby degrading the level of service and therefore potentially requiring additional lanes to maintain an acceptable Level of Service (LOS).
4) Is the existing LOS and/or delays acceptable?

The answers to these types of questions for all aspects of the roadway will assist to define what improvements should be performed.

The Reconstruction NoCIRT criteria, outlined in Exhibit 4.2.2 and Exhibit 4.2.4, may be used if a feature of the roadway does not meet Chapter 3 design criteria, and if there are no crash cluster or multiple safety concerns associated with that feature. For example, a horizontal alignment is substandard by Chapter 3 criteria in one curve, but there are no noted crash clusters associated with the curve. In that case, the curve alignment may use the criteria in this Chapter. Another design option would be the application of the HSM Analysis, as discussed in Section 4.1.

For examples of this project type, see Exhibit 3B.1 in Appendix 3B of Chapter 3.

Exhibit 4.2.2 – Reconstruction NoCIRT Design Criteria

(Applicable to all Functional Classifications except for Interstates and Freeways)

	RURAL AREA SYSTEM		URBAN AREA SYSTEM		
	Rural	**Rural Town**	**Urban**	**Urban Center**	**Suburban**
Minimum Lane Widths ①	Exhibit 4.2.4	Existing* ② Exhibits 3.7.2 Through 3.7.4 (Preferred)	Existing * ② Exhibits 3.7.2 Through 3.7.4 (Preferred)		
Minimum Shoulder Widths ①	Exhibit 4.2.4	Existing* ②④ Exhibits 3.7.2 Through 3.7.4 (Preferred)	Existing* ②④ Exhibits 3.7.2 Through 3.7.4 (Preferred)		
Minimum Median Widths ③	Existing*		Existing*		
Parking Lanes	None	See Chapter 19	See Chapter 19		
Min. Horizontal Curvature	Existing* ⑤		Existing* ⑤		
Superelevation	See Chapter 3, Section 3.3		See Chapter 3, Section 3.3		
Min. Sight Distances	Existing* ⑤		Existing* ⑤		
Roadway Tangent Cross Slopes	Exhibits 3.7.2 through 3.7.4		Exhibits 3.7.2 through 3.7.4		
Shoulder Cross Slopes	Exhibits 3.8.5 through 3.8.9		Exhibits 3.8.5 through 3.8.9		
Min Grades	Existing* ⑤		Existing* ⑤		
Max Grades	Existing* ⑤		Existing* ⑤		
Vertical Clearance	See Section 3.4.10		See Section 3.4.10		
Vertical Curvature	Existing* ⑤		Existing* ⑤		
Bridge Widths	See Chapter 5		See Chapter 5		
Guide Rail	See Chapter 12		See Chapter 12		
Clear Zone Widths	See Chapter 12		See Chapter 12		

***If the existing exceeds Chapter 3 minimum criteria, then the proposed can be reduced below existing, but may not be reduced below Chapter 3 criteria. If the existing is below Chapter 3 maximum criteria, then the proposed may be increased above existing, but should not exceed the Chapter 3 criteria.**

Note: In lieu of the above criteria, the design analysis in Section 4.1, HSM Analysis/ Benefit Cost Analysis, may be considered where it can be applied.

NOTES

① For roadways with a local classification, lanes 9 ft wide may be used on one-way streets or for divided roadways if at least a 1 ft curb offset is used or if trucks and buses are prohibited.

② Curbed sections: full shoulder widths as per Chapter 3 may be desirable

Curb, guide rail, and concrete barrier Offset: 1 ft minimum, 2 ft desirable.

③ Left shoulder width governs over median width. For urban areas, 6' minimum is needed for pedestrian refuge.

④ See Chapter 3, **Exhibit 3.8.9,** for curbed sections.

⑤ **GENERAL:** Existing horizontal curvature, vertical curvature, grades, and sight distance shall be evaluated against minimum criteria in Chapter 3. If a crash or operational problem exists, apply the standards in Chapter 3 to that geometric feature; however, consider maintaining consistency throughout the roadway corridor, where fluctuations in lane and shoulder widths is not desirable. For projects with multiple sites experiencing crash problems, Chapter 3 Design Standards shall be used for the Design Criteria. If applying these design standards are not feasible, or the design criteria is less than new construction standards, a design exception request shall be prepared if it is a controlling criteria feature. Another option would be the application of the HSM Project Specific and Benefit Cost Analysis, discussed in Section 4.1. In addition, appropriate safety and other mitigation measures shall be applied to enhance and upgrade these geometric features for extended service life and safer operations. If HSM Analysis is not used and the Chapter 3 Design Standards are not feasible, a design exception request shall be prepared.

MINIMUM HORIZONTAL RADIUS: 15 mph or less below the design speed of the proposed project.

SUPERELEVATION: To be designed, per Chapter 3, Section 3.3, to correspond to the horizontal radius.

MINIMUM /MAXIMUM VERTICAL CURVATURE AND GRADES: 20 mph or less below the AASHTO Green Book applicable value for SSD, HLSD, or Grade for the design speed of the proposed project.

SIGHT DISTANCE: When evaluating sight distance parameters, consider horizontal and vertical curvature together.

EXHIBIT 3.7.2 – MATRIX OF DESIGN VALUES – ARTERIAL

<table>
<tr><th colspan="2"></th><th>Rural</th><th>Rural Town</th><th>Suburban</th><th>Urban</th><th>Urban Core</th></tr>
<tr><td rowspan="13">Roadway</td><td>Freight Corridors</td><td colspan="5">Refer to Chapter 16, Section 16.5.1, for recommended lane and shoulder widths.</td></tr>
<tr><td>Plain People Community</td><td colspan="5">Refer to Chapter 17, Plain People Community Considerations.</td></tr>
<tr><td>Parking / Loading Lane</td><td colspan="5">Refer to Chapter 19, Parking.</td></tr>
<tr><td>Horizontal Curvature</td><td colspan="5">Refer to the Green Book.</td></tr>
<tr><td>Stopping Sight Distances (Minimum)</td><td colspan="5">Refer to the Green Book.</td></tr>
<tr><td>Passing Sight Distances (Minimum)</td><td colspan="5">Refer to Exhibit 3.1.2</td></tr>
<tr><td>Cross Slopes (minimum)</td><td colspan="5">2.0%
Also:
1. In curbed areas with longitudinal slopes of 1.0 % or less, 3.0% cross slopes may be used on tangents</td></tr>
<tr><td rowspan="2">Cross Slopes (maximum)</td><td>8.0%</td><td colspan="2">6.0% to 8.0%</td><td>6.0%</td><td>4.0%</td></tr>
<tr><td colspan="5">For Low Speed Urban and Urban Core, refer to the Green Book, Low-Speed Streets in Urban Areas</td></tr>
<tr><td>Vertical Grades (minimum)</td><td colspan="5">0.5%
Recommended minimum grade of 0.75% on curbed sections.</td></tr>
<tr><td>Vertical Grades (maximum)</td><td colspan="5">Refer to the Green Book.</td></tr>
<tr><td>Vertical Clearance (minimum)</td><td colspan="5">16'-6" Refer to Section 3.4.10.</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="4">Roadside</td><td>Sidewalk</td><td colspan="5" rowspan="3">Refer to Chapter 13, Pedestrian Facilities.
Also:
1. Where pedestrian traffic is anticipated, provisions for a sidewalk should be considered (also Chapter 13).
2. The preferred curb height is 6 inches. However, a curb height of 8 inches may be used to accommodate future resurfacing.</td></tr>
<tr><td>Buffer</td></tr>
<tr><td>Curb</td></tr>
<tr><td>Clear Zone Widths</td><td colspan="5">Refer to Chapter 12, Roadside Design.</td></tr>
<tr><td>Bridge</td><td>Bridge Widths</td><td colspan="5">Refer to Chapter 5, Bridges and Tunnels.</td></tr>
</table>

4.2.2 – Resurfacing, Restoration, and Rehabilitation (3R) Projects

Resurfacing, restoration, and rehabilitation (3R) projects are construction projects on existing roads that maintain the roadway's functional classification. They include improvements to all Functional Classifications (Interstates, Freeway and Expressways, Arterials, Collectors, and Local Roads).

3R projects are typically undertaken to extend the service life of a roadway and/or improve the pavement structural and functional capacity while maintaining the existing roadway alignment, but they may include limited geometric changes to improve safety.

Although all 3R projects are defined as construction projects on existing roads, they often include work other than resurfacing, restoration, and rehabilitation, such as upgrading roadside barrier, sidewalks, curb ramps, transit stops, and adding traffic signals. Most 3R projects, even if they are not initiated originally by pavement resurfacing needs, are scheduled for implementation in conjunction with pavement resurfacing to obtain economies of scale.

3R project design may require the designer to work within a number of constraints, including existing geometric elements, existing land uses, existing utilities, existing pavement and drainage structures, etc. and to "thread" a proposed improvement design through the constraints to achieve an optimum combination of design elements.

Unlike a New Construction project design, which must rely solely on dimensional criteria because no safety and traffic operational performance history exist, 3R project design involves existing roadways that have safety and traffic operational performance histories that can be used to identify geometric features that may need improvement; and, as discussed in Section 4.0, also determine and evaluate the performance measures associated with the project.

3R projects typically do not include capacity improvements, major realignment, or major upgrading of geometric features, but they may include limited improvements to highway geometry and other roadway features and safety appurtenances. Exhibit 3B.1 in Appendix 3B provides a list of typical 3R improvements, as appropriate to their respective Functional Classification.

The terms resurfacing, restoration, and rehabilitation are defined as follows:

1) **Resurfacing**. Application of a new or recycled layer(s) of pavement material to existing pavements, shoulders and/or bridge decks.

2) **Restoration**. Improvements to return the pavement, shoulders and/or bridges to an acceptable condition to ensure safe operations for a substantial period.

3) **Rehabilitation**. Improvements to remove and replace major structural elements of a highway or bridge to an acceptable condition. This includes pavement rehabilitation as defined in Publication 242, *Pavement Policy Manual*.

Resurfacing projects that do not add structural capacity to the pavement may be classified as Pavement Preservation projects, as defined in Publication 242, *Pavement Policy Manual*. For examples of this project type, see Exhibit 3B.1in Appendix 3B. Refer to Chapter 5 for geometric design criteria for bridge projects.

Also, see Exhibit 4.7.1 for a list of low cost safety improvement measures to consider, as applicable.

4.2.2.a – Resurfacing, Restoration, and Rehabilitation (3R) Criteria

Geometric design improvements should be considered as part of a 3R project in the following situations:

- An analysis of the crash history of the existing road identifies one or more crash patterns that are potentially correctable by a viable design improvement, or
- A design improvement would reduce sufficient crashes over its service life to be cost effective, i.e., the anticipated crash reduction benefits over the service life of the project should exceed the improvement implementation cost, or
- An analysis of the traffic operational Level of Service (LOS) indicates that the LOS is currently worse than the highway agency's target LOS for the facility or will become worse than the target LOS within the service life of the planned pavement resurfacing. Refer to Chapter 2, *Design Controls*, Section 2.4.2.a, for additional information.

If one or all of the above is applicable, Chapter 3 criteria, Reconstruction NoCIRT criteria, or the application of the HSM Analysis, (discussed in Section 4.1), should be considered for the design criteria. If Chapter 3 or Reconstruction NoCIRT criteria is determined to be not applicable, refer to the design criteria for 3R projects provided in **Exhibit 4.2.3** and Exhibit 4.2.4. See Publication 242, *Pavement Policy Manual*, for additional guidance on 3R projects.

Exhibit 4.2.3 3R Design Criteria

(Applicable to all Functional Classifications)

<table>
<tr><th rowspan="2"></th><th colspan="2">RURAL AREA SYSTEM</th><th colspan="3">URBAN AREA SYSTEM</th></tr>
<tr><th>Rural</th><th>Rural Town</th><th>Urban</th><th>Urban Center</th><th>Suburban</th></tr>
<tr><td rowspan="2">Minimum Lane Widths ①</td><td>Interstates and Freeways
Existing *
Exhibit 3.7.1
(Preferred)</td><td rowspan="2">Existing* ②
Exhibits 3.7.2
Through 3.7.4 (Preferred)</td><td>Interstates and Freeways
Existing* ②
Exhibit 3.7.1</td><td colspan="2" rowspan="2">Existing* ②
Exhibits 3.7.2 through 3.7.4 (Preferred)</td></tr>
<tr><td>All Other Classifications
Exhibit 4.2.4</td><td>All Other Classifications
Existing* ②
Exhibits 3.7.2 through 3.7.4 (Preferred)</td></tr>
<tr><td rowspan="2">Minimum Shoulder Widths ①</td><td>Interstates and Freeways
Existing *
Exhibit 3.7.1
(Preferred)</td><td rowspan="2">Existing* ②④
Exhibits 3.7.2
Through 3.7.4 (Preferred)</td><td>Interstates and Freeways
Existing* ②④
Exhibits 3.7.2 through 3.7.4 (Preferred)</td><td colspan="2" rowspan="2">Existing* ②④
Exhibits 3.7.2 through 3.7.4 (Preferred)</td></tr>
<tr><td>All Other Classifications
Exhibit 4.2.4</td><td>All Other Classifications
Existing* ②
Exhibits 3.7.2 through 3.7.4 (Preferred)</td></tr>
<tr><td>Minimum Median Widths ③</td><td colspan="2">Existing*</td><td colspan="3">Existing*</td></tr>
<tr><td>Parking Lanes</td><td>None</td><td>See Chapter 19</td><td colspan="3">See Chapter 19</td></tr>
<tr><td>Min. Horizontal Curvature</td><td colspan="2">Existing* ⑦</td><td colspan="3">Existing* ⑦</td></tr>
<tr><td>Superelevation ⑦</td><td colspan="2">Existing*</td><td colspan="3">Existing*</td></tr>
<tr><td>Min. Sight Distances</td><td colspan="2">Existing* ⑦</td><td colspan="3">Existing* ⑦</td></tr>
<tr><td>Roadway Tangent Cross Slopes ⑥</td><td colspan="2">Tangent: 2.0% (Desirable)
1.0% (Minimum). For existing cross slopes between 1.5% and 2.0%, do not reduce below existing.
For existing cross slopes below 1.5%, increase to 1.5%. 2.0% should be considered where practicable.
For retained cross slopes less than 2.0%, confirm adequate drainage.</td><td colspan="3">Tangent: 2.0% (Desirable)
Match Existing* (Minimum)
May increase to 3% to address drainage issues</td></tr>
<tr><td>Shoulder Cross Slopes ⑤ ⑥</td><td colspan="2">Existing*; however, the algebraic difference between the lane/shoulder cross slopes should not exceed 8.0%
For shoulder rounding details when superelevation is greater than 6.0%, see Exhibit 3.8.6</td><td colspan="3">Existing*; however, the algebraic difference between the lane/shoulder cross slopes should not exceed 8.0%
For shoulder rounding details when superelevation is greater than 6.0%, see Exhibit 3.8.6</td></tr>
</table>

Min Grades	Existing* 7	Existing* 7
Max Grades	Existing* 7	Existing* 7
Vertical Clearance	See Section 3.4.10	See Section 3.4.10
Vertical Curvature	Existing* 7	Existing* 7
Bridge Widths	See Chapter 5	See Chapter 5
Guide Rail	See Chapter 12	See Chapter 12
Clear Zone Widths	See Chapter 12	See Chapter 12

***If the existing exceeds Chapter 3 minimum criteria, then the proposed can be reduced below existing, but may not be reduced below Chapter 3 criteria.**
If the existing is below Chapter 3 maximum criteria, then the proposed may be increased above existing, but should not exceed the Chapter 3 criteria.

Note: In lieu of the above criteria, the design analysis in Section 4.1, *HSM Analysis/ Benefit Cost Analysis*, may be considered where it can be applied.

NOTES

① For roadways with a local classification, lanes 9 ft wide may be used on one-way streets or for divided roadways if at least a 1 ft curb offset is used or if trucks and buses are prohibited.

② Curbed sections: full shoulder widths as per Chapter 3 may be desirable.
Curb, guide rail, and concrete barrier offset: 1 ft minimum, 2 ft desirable.

③ Left shoulder width governs over median width. For urban area, 6' minimum is needed for pedestrian refuge.

④ See Chapter 3, **Exhibit 3.8.9,** for curbed sections.

⑤ In order to increase the amount of drainage capacity or to include reconstruction of the shoulder, the shoulder cross slopes may be increased.

⑥ If the lane is widened, the widening portion of the lane should be constructed at the same slope as the existing lane. The shoulder slope should begin at the edge of the widened lane. When the pavement structure is being extended for the full width of the shoulder, the shoulder slope should begin at the edge of the design width of the lane. Typical sections should indicate the shoulder area in these cases even though the materials used may be paid for separately.

⑦ **GENERAL:** If a crash problem exists, apply the standards in Chapter 3 to that geometric feature. If the Chapter 3 Design Standards are not feasible, a design exception request shall be prepared; however, consider maintaining consistency throughout the roadway corridor, where fluctuations in lane and shoulder widths is not desirable. For projects with multiple sites experiencing crash problems, Chapter 3 Design Standards shall be used for the Design Criteria. If applying these design standards are not feasible, or the design criteria is less than new construction standards, a design exception request shall be prepared if it is a controlling criteria feature. Another option would be the application of the HSM Project Specific and Benefit Cost Analysis, discussed in Section 4.1. In addition, appropriate safety and other mitigation measures shall be applied to enhance and upgrade these geometric features for extended service life and safer operations. If HSM Analysis is not used and the Chapter 3 Design Standards are not feasible, a design exception request shall be prepared.

HORIZONTAL CURVATURE: Additionally, consider friction overlays and improved signing & pavement markings.

SUPERELEVATION: Where the superelevation of an existing curve is less than the design superelevation value in the Chapter 3 Design Standards by more than 1 percent, consider improving the superelevation as close as practicable to the Chapter 3 Design Standards.

SIGHT DISTANCE: When evaluating sight distance parameters, consider the preceding criteria on horizontal and vertical curvature together.