US Army Corps
of Engineers
Afghanistan Engineer District

AED Design Requirements:
Superelevation Road Design

Various Locations,
Afghanistan

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AED DESIGN REQUIREMENTS
FOR
SUPERELEVATION ROAD DESIGN
VARIOUS LOCATIONS,
AFGHANISTAN

1. General

The purpose of this document is to provide requirements to Contractors for any project requiring the design and construction of superelevation road design.

2. Superelevation

Superelevation of a road is required to offset the centripetal acceleration that acts toward the center of curvature on a horizontal curve. For paved roads the rate of superelevation (e) is a function of the radius of curvature (R) of the road and the vehicle speed (V). The Islamic Republic of Afghanistan, Ministry of Public Works, Interim Road and Highway Standards, paragraph IX (c) limits the maximum superelevation rate (e_{max}) for all roads is 10%. Table 1 shown below will be used to determine the superelevation rates for horizontal curves of a known radius, a known vehicles speed and a maximum superelevation rate of 10%. If a horizontal curve has a sufficiently large radius and low vehicle speed so that no e is identified on Table 1, no superelevation is required for the curve. Additionally the minimum radius of a curve can be obtained by the vehicle speed and the maximum e.

Table 1. Minimum Radii for Design Superelevation Rates, Design Speed and e_{max}=10%

e (%)	V_d = 20 km/h R (m)	V_d = 30 km/h R (m)	V_d = 40 km/h R (m)	V_d = 50 km/h R (m)	V_d = 60 km/h R (m)	V_d = 70 km/h R (m)	V_d = 80 km/h R (m)	V_d = 90 km/h R (m)	V_d = 100 km/h R (m)	V_d = 110 km/h R (m)	V_d = 120 km/h R (m)	V_d = 130 km/h R (m)
1.5	197	454	790	1110	1520	2000	2480	3010	3690	4250	4960	5410
2.0	145	333	580	815	1120	1480	1840	2230	2740	3160	3700	4050
2.2	130	300	522	735	1020	1340	1660	2020	2480	2860	3360	3680
2.4	118	272	474	669	920	1220	1520	1840	2260	2620	3070	3370
2.6	108	249	434	612	844	1120	1390	1700	2080	2410	2830	3110
2.8	99	229	399	564	778	1030	1290	1570	1920	2230	2620	2880
3.0	91	211	368	522	720	952	1190	1460	1790	2070	2440	2690
3.2	85	196	342	485	670	887	1110	1360	1670	1940	2280	2520
3.4	79	182	318	453	626	829	1040	1270	1560	1820	2140	2370
3.6	73	170	297	424	586	777	974	1200	1470	1710	2020	2230
3.8	68	159	278	398	551	731	917	1130	1390	1610	1910	2120
4.0	64	149	261	374	519	690	866	1060	1310	1530	1810	2010
4.2	60	140	245	353	490	652	820	1010	1240	1450	1720	1910
4.4	56	132	231	333	464	617	777	953	1180	1380	1640	1820
4.6	53	124	218	315	439	586	738	907	1120	1310	1560	1740
4.8	50	117	206	299	417	557	703	864	1070	1250	1490	1670
5.0	47	111	194	283	396	530	670	824	1020	1200	1430	1600
5.2	44	104	184	269	377	505	640	788	975	1150	1370	1540
5.4	41	98	174	256	359	482	611	754	934	1100	1320	1480
5.6	39	93	164	243	343	461	585	723	896	1060	1270	1420
5.8	36	88	155	232	327	441	561	693	860	1020	1220	1370
6.0	33	82	146	221	312	422	538	666	827	976	1180	1330
6.2	31	77	138	210	298	404	516	640	795	941	1140	1280
6.4	28	72	130	200	285	387	496	616	766	907	1100	1240
6.6	26	67	121	191	273	372	476	593	738	876	1060	1200
6.8	24	62	114	181	261	357	458	571	712	846	1030	1170
7.0	22	58	107	172	249	342	441	551	688	819	993	1130
7.2	21	55	101	164	238	329	425	532	664	792	963	1100
7.4	20	51	95	156	228	315	409	513	642	767	934	1070
7.6	18	48	90	148	218	303	394	496	621	743	907	1040
7.8	17	45	85	141	208	291	380	479	601	721	882	1010
8.0	16	43	80	135	199	279	366	463	582	699	857	981
8.2	15	40	76	128	190	268	353	448	564	679	834	956
8.4	14	38	72	122	182	257	339	432	546	660	812	932
8.6	14	36	68	116	174	246	326	417	528	641	790	910
8.8	13	34	64	110	166	236	313	402	509	621	770	888
9.0	12	32	61	105	158	225	300	386	491	602	751	867
9.2	11	30	57	99	150	215	287	371	472	582	731	847
9.4	11	28	54	94	142	204	274	354	453	560	709	828
9.6	10	26	50	88	133	192	259	337	432	537	685	809
9.8	9	24	46	81	124	179	242	316	407	509	656	786
10.0	7	19	38	68	105	154	210	277	358	454	597	739

3. Superelevation Transition

A fully superelevated road section is obtained using a superelevation transition (T) from the normal crown of the road. The superelevation transition is composed of a superelevation runoff (L_r) and tangent runout (L_t). The superelevation runoff is the length of the roadway required to change the outside (superelevated) lane cross slope from a flat cross slope (0%) to a fully superelevated section. The length of the superelevation runoff is obtained from Equation 1 as shown below:

Equation 1 $L_r=[((w*n_1)*e_d)*b_w]/\Delta$

Where:

- L_r=minimum length of superelevation runoff (m)
- w=width of one traffic lane (m)
- n_1=number of lanes rotated
- e_d=design superelevation rate (%)

b_w=adjustment factor for number of lanes rotated=$[1+0.5(n_1-1)]/n_1$
Δ=maximum relative gradient (%) from Table 2

Table 2. Maximum Relative Gradients

Metric		
Design speed (km/h)	Maximum relative gradient (%)	Equivalent maximum relative slope
20	0.80	1:125
30	0.75	1:133
40	0.70	1:143
50	0.65	1:154
60	0.60	1:167
70	0.55	1:182
80	0.50	1:200
90	0.47	1:213
100	0.44	1:227
110	0.41	1:244
120	0.38	1:263
130	0.35	1:286

The tangent runout is the length of the roadway required to change the outside (superelevated) lanes from a normal cross crown cross slope to a flat cross slope (0%). The length of the tangent runout is obtained from equation 2 as shown below:

Equation 2 $L_t=(e_{NC}/e_d)L_r$

Where:

L_t=minimum length of tangent runout (m)
e_{NC}=normal cross slope rate (%)
e_d=design superelevation rate (%)
L_r=minimum length of superelevation runoff (m)

4. Superelevation Transition Placement

The proper placement of the superelevation transition (superelevation runoff and tangent runout) in relationship to the beginning of the curve (PC) or end of curve (PT) may have an effect of the safety and driver comfort along the curve. The placement of the superelevation runoff shall be with 1/3 of the runoff length on the curve and 2/3 of the runoff length on the tangent. The tangent runout will be immediately prior to the superelevation runoff when entering a curve and immediately after the superelevation runoff when exiting a curve.

5. Traveled Way Widening

Traveled way widening for horizontal curves may be required to make the operating conditions on the curve similar to those on the tangents. The traveled way widening values for two-lane highway with the specified roadway widths, curve radii and a WB-15 truck are obtained from Table 3 shown below.

Table 3. Calculated and Design Values for Travel Way Widening

Metric																		
Radius of curve (m)	Roadway width = 7.2 m						Roadway width = 6.6 m						Roadway width = 6.0 m					
	Design Speed (km/h)						Design Speed (km/h)						Design Speed (km/h)					
	50	60	70	80	90	100	50	60	70	80	90	100	50	60	70	80	90	100
3000	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.3	0.3	0.3	0.5	0.5	0.6	0.6	0.6	0.6
2500	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.3	0.3	0.3	0.5	0.6	0.6	0.6	0.6	0.6
2000	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.3	0.3	0.3	0.3	0.4	0.6	0.6	0.6	0.6	0.6	0.7
1500	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.3	0.4	0.4	0.4	0.4	0.6	0.6	0.7	0.7	0.7	0.7
1000	0.1	0.1	0.1	0.2	0.2	0.2	0.4	0.4	0.4	0.5	0.5	0.5	0.7	0.7	0.7	0.8	0.8	0.8
900	0.1	0.1	0.2	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.8	0.9
800	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.8	0.8	0.9	0.9
700	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.8	0.8	0.9	0.9	1.0
600	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.9	0.9	0.9	1.0	1.0
500	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1
400	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2
300	0.5	0.6	0.6	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.4	1.4
250	0.6	0.7	0.8	0.8	0.9		0.9	1.0	1.1	1.1	1.2		1.2	1.3	1.4	1.4	1.5	
200	0.8	0.9	1.0	1.0			1.1	1.2	1.3	1.3			1.4	1.5	1.6	1.6		
150	1.1	1.2	1.3	1.3			1.4	1.5	1.6	1.6			1.7	1.8	1.9	1.9		
140	1.2	1.3					1.5	1.6					1.8	1.9				
130	1.3	1.4					1.6	1.7					1.9	2.0				
120	1.4	1.5					1.7	1.8					2.0	2.1				
110	1.5	1.6					1.8	1.9					2.1	2.2				
100	1.6	1.7					1.9	2.0					2.2	2.3				
90	1.8						2.1						2.4					
80	2.0						2.3						2.6					
70	2.3						2.6						2.9					

Notes: Values shown are for WB-15 design vehicle and represent widening in meters. For other design vehicles, use adjustments in Exhibit 3-48.
Values less than 0.6 m may be disregarded.
For 3-lane roadways, multiply above values by 1.5.
For 4-lane roadways, multiply above values by 2.

Travel lane widening for alternative vehicle types can be obtained by adding the values defined in Table 4 for the appropriate curve radius and vehicle type to the value obtained from Table 3.

Table 4. Adjustments for Traveled Way Widening Values

Metric							
Radius of curve (m)	Design vehicle						
	SU	WB–12	WB–19	WB–20	WB–20D	WB–30T	WB–33D
3000	–0.3	–0.3	0.0	0.0	0.0	0.0	0.1
2500	–0.3	–0.3	0.0	0.0	0.0	0.0	0.1
2000	–0.3	–0.3	0.0	0.0	0.0	0.0	0.1
1500	–0.4	–0.3	0.0	0.1	0.0	0.0	0.1
1000	–0.4	–0.4	0.1	0.1	0.0	0.0	0.2
900	–0.4	–0.4	0.1	0.1	0.0	0.0	0.2
800	–0.4	–0.4	0.1	0.1	0.0	0.0	0.2
700	–0.4	–0.4	0.1	0.1	0.0	0.0	0.3
600	–0.5	–0.4	0.1	0.1	0.0	0.1	0.3
500	–0.5	–0.4	0.1	0.2	0.0	0.1	0.4
400	–0.5	–0.4	0.2	0.2	0.0	0.1	0.5
300	–0.6	–0.5	0.2	0.3	–0.1	0.1	0.6
250	–0.7	–0.5	0.2	0.3	–0.1	0.1	0.8
200	–0.8	–0.6	0.3	0.4	–0.1	0.2	1.0
150	–0.9	–0.7	0.4	0.6	–0.1	0.2	1.3
140	–0.9	–0.7	0.4	0.6	–0.1	0.2	1.4
130	–1.0	–0.7	0.5	0.6	–0.2	0.2	1.5
120	–1.1	–0.8	0.5	0.7	–0.2	0.3	1.6
110	–1.1	–0.8	0.6	0.8	–0.2	0.3	1.7
100	–1.2	–0.9	0.6	0.8	–0.2	0.3	1.9
90	–1.3	–0.9	0.7	0.9	–0.2	0.3	2.1
80	–1.4	–1.0	0.8	1.1	–0.2	0.4	2.4
70	–1.6	–1.1	0.9	1.2	–0.3	0.5	2.8

Notes: Adjustments are applied by adding to or subtracting from the values in Exhibit 3-47.
Adjustments depend only on radius and design vehicle; they are independent of roadway width and design speed.
For 3-lane roadways, multiply above values by 1.5.
For 4-lane roadways, multiply above values by 2.0.

Very little benefit is gained from small amount of widening. Therefore the minimum widening will be 0.6 meters with widening amounts less than 0.6 meters being disregarded. Widening should be applied on the inside edge of the curve only and the widening should transition over the superelevation runoff length with 2/3 of the transition length along the tangent and 1/3 of the transition length along the curve. The edge of the traveled way through the widening transition should be a smooth curve with the transition ends avoiding an angular break at the pavement edge.

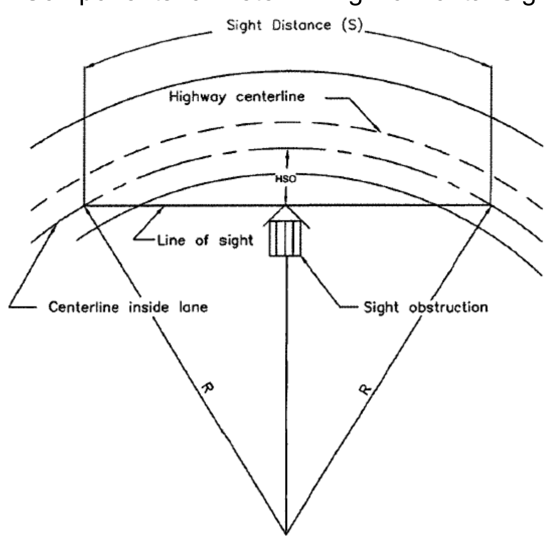
6. Stopping Sight Distance

Required stopping sight distance for various design speeds is presented in Table 5. The horizontal sightline offset in meters from the center of the inside travel lane is obtained from Equation 3 as shown in Exhibit 1.

Table 5. Stopping Sight Distance

Metric				
Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance	
			Calculated (m)	Design (m)
20	13.9	4.6	18.5	20
30	20.9	10.3	31.2	35
40	27.8	18.4	46.2	50
50	34.8	28.7	63.5	65
60	41.7	41.3	83.0	85
70	48.7	56.2	104.9	105
80	55.6	73.4	129.0	130
90	62.6	92.9	155.5	160
100	69.5	114.7	184.2	185
110	76.5	138.8	215.3	220
120	83.4	165.2	248.6	250
130	90.4	193.8	284.2	285

Exhibit 1. Components for Determining Horizontal Sight Distance



Equation 3 $HSO=R[1-\cos(28.65S/R)]$

Where:

HSO=horizontal sightline offset (m)
S=stopping sight distance (m)
R=radius of curve (m)

Where sufficient stopping sight distance is not available due to sight obstructions, alternative designs such as increasing the offset to the obstruction, increasing the radius or reducing the design speed should be considered for safety and economic reasons. The selected alternative should not include shoulder widths on the inside of the curve in excess of 3.6 meters to eliminate the chance of drivers using the shoulder as a passing or travel lane.

7. Passing Sight Distance

The minimum passing sight distance for a two-lane road is approximately four times as great as the minimum stopping sight distance at the same design speed. This greater distance may result is the sight line extending beyond the normal road right-of-way. For these reasons, passing sight distance should be limited to tangents and very flat curves.

8. Design Considerations

The following design considerations, in addition to the criteria listed above, should be reviewed for all horizontal curves to endure a safe design.

For a given design speed the minimum radius of curvature for that speed should be avoided wherever practical. The designer should attempt to use the largest radius possible saving the minimum radius curves for the most critical conditions.

Sudden sharp curves should not be introduces at the end of a long tangent section or large radius curves. Where a sharp curve is necessary, it should be preceded by a series of successively sharper curves.

For small deflection angles, curves should be sufficiently long to avoid the appearance of a kink. The minimum length for a horizontal curve on a main highway should be three times the design speed in km/h.

Compound curves should be avoided wherever possible. If the use of compound curves is unavoidable the radius of the flatter curve should not be more than 50 percent greater than the radius of the sharper curve.

Reverse curves should be avoided. The distance between reverse curves should be the sum of the superelevation runoff lengths and the tangent runout lengths.

Short tangent sections of roadway between two curves in the same direction should be avoided except where very unusual topographic or fight-of-way conditions make other alternatives impractical. A single large radius curve or two curves of smaller radius resulting is a longer tangent section should be investigates.

9. As-Builts

Upon completion of construction of the roadway, The Contractor shall submit editable CAD format As-Built drawings. The drawing shall show the final product as it was installed in the field, with the exact dimensions, locations, materials used and any other changes made to the original drawings. Refer to Contract Sections 01335 and 01780A of the specific project for additional details.