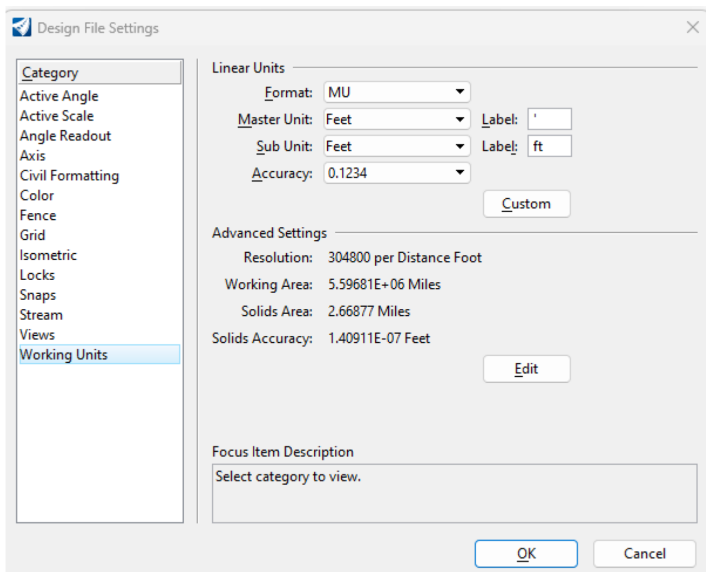
ORD Lesson 3: Roadway Curves & Spirals

Learning Objective: This lesson is intended to teach you how to compute and locate the transition locations on both a simple (circular) curve and spiraled curve.

<u>Task 1: Getting Started</u>

1. Open ORD and select "Browse". Locate and open *Lesson2.dgn* file used in the previous lesson.
2. Verify the working units of the drawing are in feet by doing the following:
   - Select the **File Tab** and then select **Settings**
   - Select **File** and then **Design File Settings**
   - Select "Working Units" from the Category box and verify the settings are as shown below. Once correct, select OK and return to the drawing.



<u>Important Notes:</u>
Unless otherwise noted, all tools in this exercise can be accessed using the "OpenRoads Modeling" workflow.

All alignments should be created using the civil geometry tools discussed in Lesson 2. (Do not use basic drawing tools)

Task 2: Drawing Curve Combinations for Road Design

1. Place a tangent of 1,000’ in any direction, making sure to set the Geom_Baseline feature definition to active.
2. Now, place another tangent of the same length, such that Δ (I) between the two tangents is 25 degrees.
3. Use the **Arcs** Tool to create a simple circular curve (no spirals) with a 1000’ radius between the two tangents.

4. Use the **Complex Geometry** Tool to combine your tangents and curve to create an alignment.
5. Using the table below, determine the minimum superelevation required on a two-lane roadway with a design speed of 40-mph. *Note: AASHTO specifies not to interpolate using this table and to use the values from the next lowest radius value.*

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	868	1580	2290	3130	4100	5230	6480	7870	9410	11100	12600	14100	15700	17400
RC	614	1120	1630	2240	2950	3770	4680	5700	6820	8060	9130	10300	11500	12900
2.2	543	991	1450	2000	2630	3370	4190	5100	6110	7230	8200	9240	10400	11600
2.4	482	884	1300	1790	2360	3030	3770	4600	5520	6540	7430	8380	9420	10600
2.6	430	791	1170	1610	2130	2740	3420	4170	5020	5950	6770	7660	8620	9670
2.8	384	709	1050	1460	1930	2490	3110	3800	4580	5440	6200	7030	7930	8910
3.0	341	635	944	1320	1760	2270	2840	3480	4200	4990	5710	6490	7330	8260
3.2	300	566	850	1200	1600	2080	2600	3200	3860	4600	5280	6010	6810	7680
3.4	256	498	761	1080	1460	1900	2390	2940	3560	4250	4890	5580	6340	7180
3.6	209	422	673	972	1320	1740	2190	2710	3290	3940	4540	5210	5930	6720
3.8	176	358	583	864	1190	1590	2010	2490	3040	3650	4230	4860	5560	6320
4.0	151	309	511	766	1070	1440	1840	2300	2810	3390	3950	4550	5220	5950
4.2	131	270	452	684	960	1310	1680	2110	2590	3140	3680	4270	4910	5620
4.4	116	238	402	615	868	1190	1540	1940	2400	2920	3440	4010	4630	5320
4.6	102	212	360	555	788	1090	1410	1780	2210	2710	3220	3770	4380	5040
4.8	91	189	324	502	718	995	1300	1640	2050	2510	3000	3550	4140	4790
5.0	82	169	292	456	654	911	1190	1510	1890	2330	2800	3330	3910	4550
5.2	73	152	264	413	595	833	1090	1390	1750	2160	2610	3120	3690	4320
5.4	65	136	237	373	540	759	995	1280	1610	1990	2420	2910	3460	4090
5.6	58	121	212	335	487	687	903	1160	1470	1830	2230	2700	3230	3840
5.8	51	106	186	296	431	611	806	1040	1320	1650	2020	2460	2970	3560
6.0	39	81	144	231	340	485	643	833	1060	1330	1660	2040	2500	3050

Table 3-8 A Policy on Geometric Design of Highways and Streets 7th Edition (AASHTO)

e = __________%

6. Using the superelevation value determined in Step 4 and a Δ value of 0.57%, use the equation and table below to determine the transition length (L_r):

$$L_r = \frac{(wn_1)\, e_d}{\Delta}(b_w)$$

where:

L_r = minimum length of superelevation runoff, ft

w = width of one traffic lane, ft (typically 12 ft)

n_1 = number of lanes rotated

e_d = design superelevation rate, percent

b_w = adjustment factor for number of lanes rotated

Δ = maximum relative gradient, percent

Equation 3-23. A Policy on Geometric Design of Highway and Streets 7th Edition (AASHTO)

L_r = __________ feet

7. Now, compute the length of transition runout (L_t) using a 2% normal crown and the formula presented below:

$$L_t = \frac{e_{NC}}{e_d} L_r$$

where:

Lt = minimum length of tangent runout, ft

eNC = normal cross slope rate, percent

ed = design superelevation rate, percent

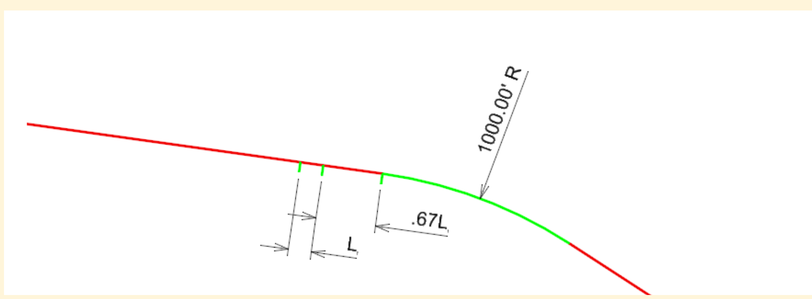
Lr = minimum length of superelevation runoff, ft

Equation 3-24. A Policy on Geometric Design of Highway and Streets 7th Edition (AASHTO)

L_t = ____________ feet

8. Change the workflow from *OpenRoads Modeling* to *Drawing* and select the Annotate Ribbon.
9. Using the curve and tangents that you drew in steps 1 through 3 and the dimensioning tools, dimension the following on the left side of the curve only (the right side is identical). Read the notes below before dimensioning.

> **<u>Important Note:</u>**
>
> AASHTO states *"The proportion of runoff length (L_r) placed on the tangent varies from 0.6 to 0.8 (i.e. 60 to 80 percent) with a large majority of agencies using 0.67"*. Therefore, for this lesson, let's use 0.67 (or 67%).

> **<u>Important Note:</u>**
>
> To place the dimensions on the tangent, you may need to use the basic drawing tools to create a vertical line perpendicular to the tangent (using the place line and perpendicular snaps) at the end of the curve. Then, use the Move Parallel Tool to place copies of the line at the correct distance from the end of the curve, similar to what's shown below (except with actual values).
>
> 
>

   a. The tangent runout (L_t).
   b. The end of tangent runout to the beginning of the curve runoff ($0.67L_r$).
   c. The radius of the curve.

Task 3: Drawing a Reversed Road Curve

1. Switch back to the *OpenRoads Modeling* workflow.
2. Add another 1000’ tangent to the left side of your original tangent. This time, change Δ (I) to 20 degrees, in the opposite direction of the original curve (creating a reverse curve).
3. Repeat Steps 4 through 6 in Task 2 to design and draw a curve that will leave a minimum of 300’ of normal crowned roadway between the tangent runouts of each curve. Using the table below, be sure to select a radius for your curve that **does** require the use of spirals.
4. Use the Complex Geometry tool to combine your alignment created in Task 2 to your newly created tangent/curve.

Helpful Tips:

- The table below presents the allowable maximum radius of a curve in which spirals should be used (i.e. radii greater than the values presented in table do not need a spiral).
- Remember to create a spiraled curve the Spiral-Arc-Spiral Tool, as discussed in Lesson 2.
- Remember, for a spiraled curve, all of the superelevation transition occurs within the spiral. According to AASHTO, the length of spiral should be equal to the length of your superelevation transition (i.e $L_r = L_s$)

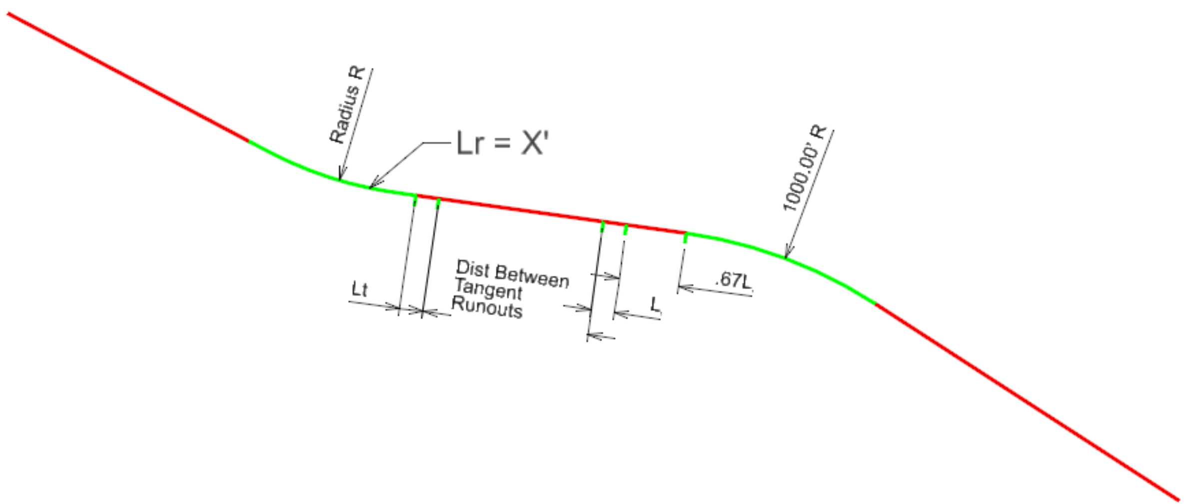
U.S. Customary	
Design speed (mph)	Maximum radius (ft)
15	114
20	203
25	317
30	456
35	620
40	810
45	1025
50	1265
55	1531
60	1822
65	2138
70	2479
75	2846
80	3238

Table 3-18. A Policy on Geometric Design of Highways and Streets 7th Edition (AASHTO)

5. Indicate the values used of e (%), L_r, and L_t for the second curve below:

e = ________%	$L_r = L_s$ = _________ feet	L_t = _________ feet

6. Use the dimensioning tools in the *Drawing* workflow and *Annotate* Ribbon to dimension the items below on the right side of the curve only (the left side is identical). Your drawing should look similar to the image shown below.
    a. The tangent runout (L_t).
    b. Length of spiral (L_s)
    c. Radius of the curve.
    d. Distance between tangent runouts.



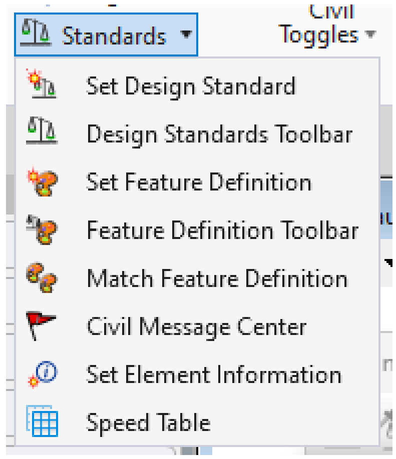
Task 4: Using Design Standards to Check Your Horizontal Geometry

In this task, we will use OpenRoads to check our horizontal geometry against your projects design standards. In this lesson, we are using the 7th edition of A Policy on Geometric Design of Highways and Streets (Green Book) published by AASHTO, which are included with OpenRoads by default. We could equally create and incorporate state or local standards if necessary.

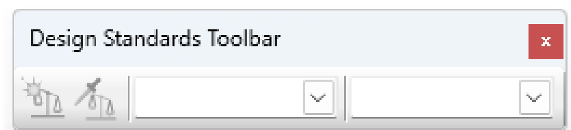
1. Reset the workflow to *OpenRoads Modeling.*
2. Use the **Transform** Tools to create a copy of the alignment you created in Tasks 2 and 3. Do not copy the dimensions.

> **Caution:**
>
> In general, you should refrain from using the **Transform** Tools to modify civil geometry, as it simplifies the geometry of the alignment and may remove some (or all) of your rules-based references.

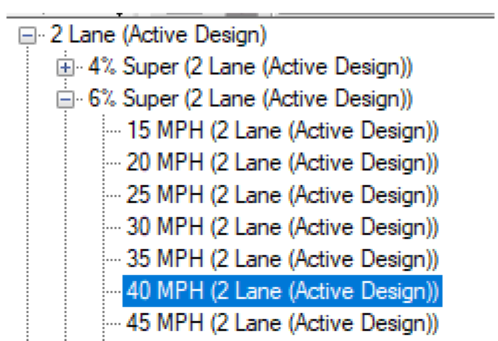
3. Select the alignment and change the radius of the left-most curve to 300’.
4. Under the Geometry Ribbon, in the General Tools toolbox, select the dropdown next to Standards and select Design Standards Toolbar.

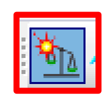


5. Once selected, the Design Standards Toolbar (shown below) will display. You can dock this by click and dragging it to your preferred location on your toolbar.

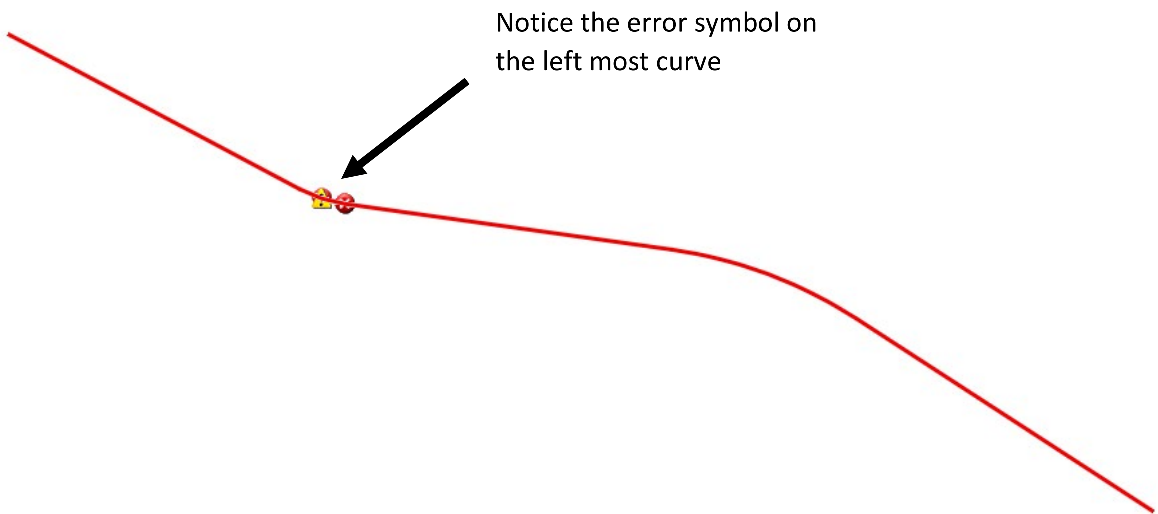


6. In the Design Standards Toolbar, using the left drop down, select standard shown below.

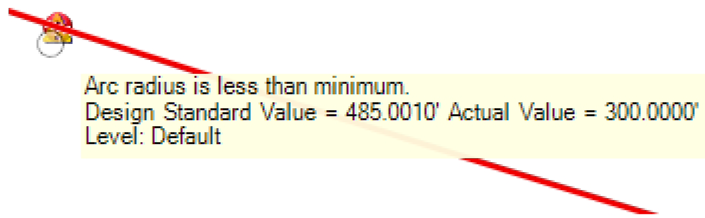




7. With the appropriate design standard selected, select the Set Design Standard icon shown on the right to toggle the design standard on.
8. The software will then prompt you to “Select Complex Element”. Select the alignment created in Step 5 of this task. Once selected, right click to exit.
9. Use the scroll wheel to zoom in on the alignment. You should notice a circle with a red x located on the leftmost curve, as shown below.



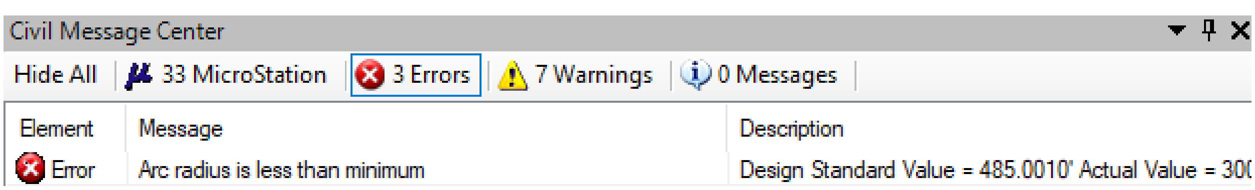
10. Use your pointer to hover over the error icon. You will notice a message appears, indicating your curve radius is below the allowable minimum of your design standard (7th Edition AASHTO Green Book).



Note: This would likely indicate you will need to adjust your curve geometry to meet the minimum radius requirement and/or ask for a design exception from the project owner.

The Design Standards Tool is a very useful check to verify your design is meeting the required specifications!

11. To see a list format of all of the errors and warnings found within your alignment, open the Civil Message Center, located under the Standards dropdown. Be sure to select “Errors” or “Warnings” along the top of the message center to see only the errors and/or warnings.



Task 5: Printing your Work

1. Change the workflow to Drawing, and select the Place Text Tool under the Annotate Ribbon.
2. Place text near your alignments that provides the values for L_r, L_t, e, and R from Tasks 2.
3. Use the **Place Fence** Tool around both your alignments from Tasks 2 and 3 along with the text you just created.
4. Use the print settings shown in the figure below.
5. Submit the following:
    a. PDF printout of your alignments and values used.
    b. Lesson2.dgn file.