Transition Curves for Roads Designers Manual

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ABSTRACT: in this manuscript we introduce an introduction about this thesis with the title Transition Curves for Roads (Designers Manual), includes the main headlines that the thesis will handle to be as a designers manual, also we introduce the equations of a transition curve which can be used by designers with a table of Excel software to facilitate the obtaining of the information needed for the designers.

1. THE DEFINITION OF THE TRANSITION CURVE:

The transition spiral is a curve whose degree – of – curve increases directly as the distance along the curve from the point of spiral.

2. WHY WE USE TRANSITION CURVES IN ROADS:

Any motor vehicle follows a transition path as it enters or leaves a circular horizontal curve. The steering change and the consequent gain or loss of lateral force cannot be effected instantly. For most curves, the average driver can follow 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 sometimes actual encroachment on adjoining lanes. In such instances, incorporation of transition curves between the tangent and the sharp circular curve, as well as between circular curves of substantially different radii, may be appropriate in order to make it easier for a driver to his or her vehicle within its own lane.

A properly designed transition curve provides a natural, easy – to - follow path for drivers, such that the lateral force increases and decreases gradually as a vehicle enters and leaves a circular curve. Transition curves minimize encroachment on adjoining traffic lanes and tend to promote uniformity in speed. A spiral transition curve simulates the natural turning path of a vehicle.

The transition curve length provides suitable location for the superelevation runoff. The transition from the normal pavement cross slop on the tangent to the fully superelevated section on the curve can be accomplished along the length of the transition curve in a manner that closely fits the speed – radius relationship for vehicles traversing the transition. Where superelevation runoff is introduce without a transition curve, usually partly on the curve and partly on the tangent, the driver approaching the curve may have to see opposite to the direction of the approaching curve when on the superelevated tangent portion in order to keep the vehicle within its lane.

A spiral transition curve also facilitates the transition in width where the travelled way is widened on a circular curve. Use of spiral transitions provides flexibility in accomplishing the widening of sharp curves.

The appearance of the highway or street is enhanced by the application of spiral transition curves. The use of spiral transition avoids noticeable breaks in the alignment as perceived by drivers at the beginning and end of circular curves.

3. **OBJECTIVES OF THIS THESIS:**

The PhD research will present a practical manual for roads designers for how to use transition curves in roads design through steps to be taken to fulfil the entire requirement needed for design the transition curve, which is: the minimum radius of curvature, maximum relative gradient, the relation between radius and superelevation according with the movement on the transition curve, minimum length of super elevation runoff, minimum length of tangent runoff, limiting super elevation rates, minimum length of transition curve, maximum radius for curves that used transition curves, maximum length of transition curve, desirable length of transition curve according to design speed, length of tangent runout, minimum transition grades and effective maximum relative gradient.

The PhD research will review the previous researches and the books that handled this subject, also the most popular equations that used now days, and the discussion of the practicality of these equations according to the restrictions mentioned above, also the most well-known software that used in the designing of transition curves and who to use it, also the newest technology that used to transfer the plans to real on the ground and how to use it, introduce a design for case study in Malaysia and the possibility to introduce a new practical equations compatible with restrictions above.

4. USEFUL EQUATIONS AND SOFTWARE:

For explain this curve, we will introduce in this article an explanations for the detail of the transition curve and its equations for one kind of transition curve that have been used by designers with its equations, and for more benefits these equations have been transformed to software design that helps to give the information needed in drawings, and those how are interested can request it from professor Adnan Bin Zulkiple.

4.1 Horizontal alignment:

Generally horizontal alignment should provide for safe and continuous operation at a uniform design speed for substation lengths of highway.

The major considerations in horizontal alignment design are safety, profile, type of facility, design speed, geotechnical features, topography, right of way cost and construction cost, in design, safety is always considered, either directly or indirectly, on freeways in metropolitan areas, alternative studies often indicate that right of way considerations influence alignment more than any other single factor topography controls both curve radius and design speed to a large extent, the design speed in turn, control sight distance, but sight distance must be considered concurrently with topography because it often demands a large radius than the design speed, all these factors must be balanced to produce an alignment which optimize the achievement of various objectives such as safety, cost, harmony with the natural contour of the land, and the same time adequate for the design classification of highway.

4.2 The simple circular curve:

$$D = 5730/R \tag{1}$$

Where:
D: degree of curvature (the angle that subtends 100m. of arc)
R: radius of the curve.

As shown in Fig. 1 -1

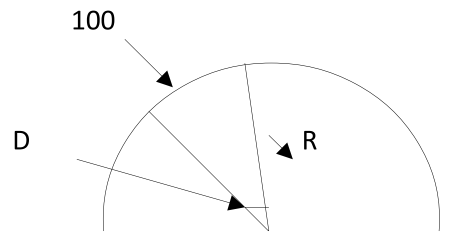


Fig. 1.

4.2.1 Arc definitions and formulas:

$$T=R\ \tan\Delta/2 \quad (2)$$

$$L=100\Delta/D=R\Delta\ (\Delta \text{ in radians}) \quad (3)$$

$$M=R\ (1-\cos\Delta/2) \quad (4)$$

$$E=R\ ((1/\cos\Delta/2)-1) \quad (5)$$

$$C=2R\ \sin\Delta/2 \quad (6)$$

$$c=2R\ \sin(\text{d.a.}) \quad (7)$$

$$\text{d.a.}=(Lc/L)(\Delta/2) \quad (8)$$

$$tx=R\sin(2\text{d.a.}) \quad (9)$$

$$ty=R(1-\cos(2\text{d.a.})) \quad (10)$$

Deflection angle in (minutes) from P.C. to P.T.(for all stations between these 2 stations)=0.3× l× D (l = the length between 2 stations) (11)

See Fig. 2.

Station on the curve between P.C. & P.T..

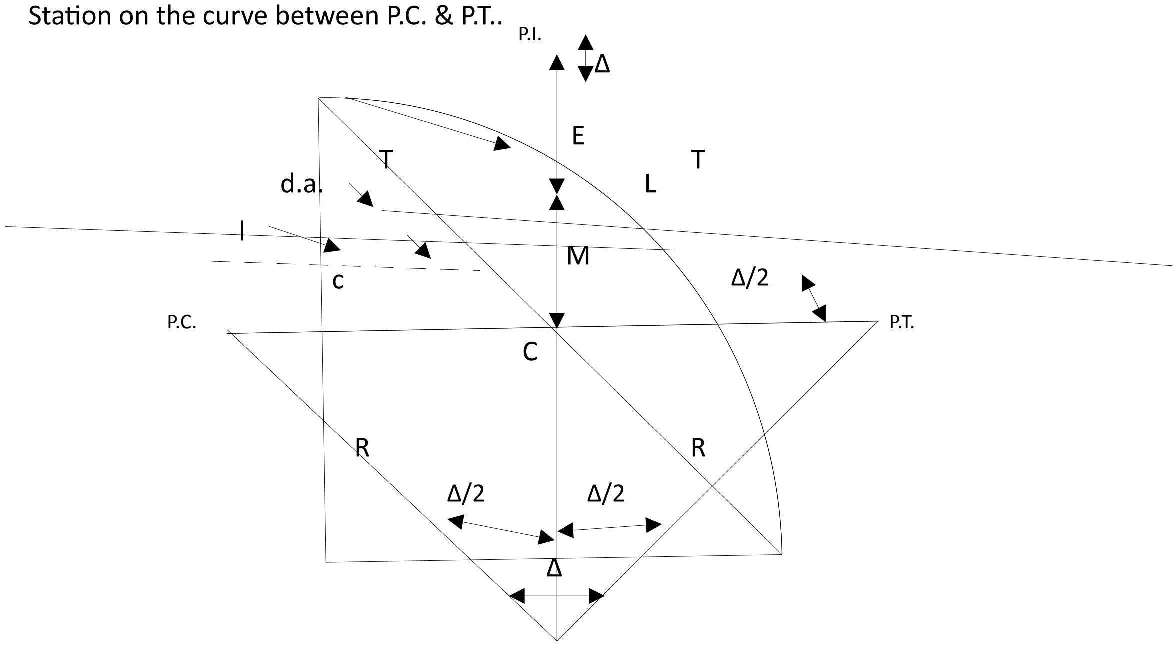


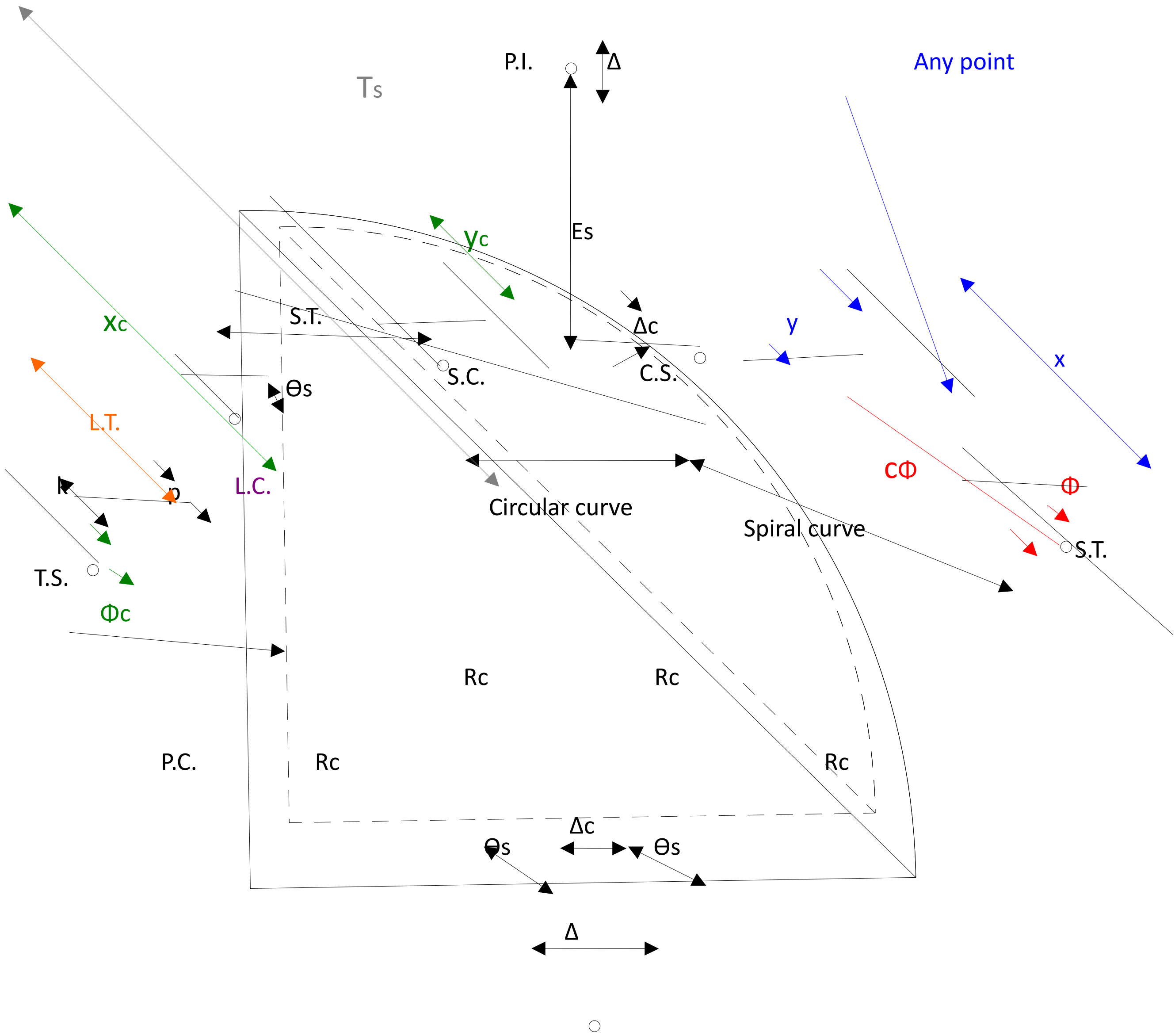
Fig. 2.

P.I.: point of intersection between 2 straight lines. (Found from survey).
P.C.: point of curvature.
P.T.: point of tangency.
L: Length of circular curve.

Δ: the angle between 2 tangents. (Usually found from survey).
From design speed we will find R, D, and from survey we will find Δ.

4.3. The circular curve with two transition curves.

The shape of the transition curve as shown in Fig. 3:



P.I.
Δ
Ts
Any point
Es
yc
Δc
y
xc
S.T.
S.C.
C.S.
x
Θs
L.T.
cΦ
Φ
L.C.
k
p
Circular curve
Spiral curve
S.T.
T.S.
Φc
Rc
Rc
P.C.
Rc
Rc
Δc
Θs
Θs
Δ

Fig. 3.

4.3.1 Formulas:

$$Ls = V^3 / 46.5\ C\ Rc \quad (12)$$
$$Ts = ((Rc + P) \tan \Delta/2) + k \quad (13)$$
$$Es = ((Rc + P)/ \cos \Delta/2) - Rc \quad (14)$$
$$P = yc - Rc\ (1 - \cos \Theta s) = yc /4 \text{ (approx.)} \quad (15)$$
$$k = x\mathbf{c} - Rc \sin \Theta s = Ls/2 \text{ (approx.)} \quad (16)$$
$$\Theta s = Ls\ Dc/200 \text{ (}\Theta s \text{ in degrees)} \quad (17)$$
$$\Theta s = Ls /2\ Rc \text{ (}\Theta s \text{ in radians)} \quad (18)$$
$$\Theta = (L/Ls)^2\ \Theta s = L^2\ Dc/200\ Ls \quad (19)$$
$$Lc = 100\ \Delta c/ Dc \quad (20)$$
$$L.C. = xc / \cos \Phi c \quad (21)$$
$$\Delta c = \Delta - Ls\ Dc /100 \quad (22)$$
$$D = (L/Ls)\ Dc \quad (23)$$
$$Dc = 200\ \Theta s/ Ls \text{ (}\Theta s \text{ in degrees)} \quad (24)$$
$$\Phi c = (\Theta s/3) - c \quad (25)$$
$$\Phi = (L/Ls)^2\ \Phi c \quad (26)$$
$$\Phi = \Theta/3 \text{ (when } \Theta < 20) \quad (27)$$
$$\Phi = \Theta/3 - c \text{ (when } \Theta > 20) \quad (28)$$
$$c_\Phi = x / \cos \Phi \quad (29)$$
$$yc = Ls\ \Theta s/3 \text{(}\Theta s \text{ in radians)} \quad (30)$$
$$xc = Ls - Ls\ \Theta s^2 / 10 \text{ (}\Theta s \text{ in radians)} \quad (31)$$
$$y = (L / Ls)^3\ yc \quad (32)$$
$$y = L\ \Theta/3 \text{ (}\Theta \text{ in radians)} \quad (33)$$
$$x = L - L\ \Theta^2 / 10 \text{ (}\Theta \text{ in radians)} \quad (34)$$
$$s.t. = yc/ \sin \Theta s \quad (35)$$
$$L.C. = yc/ \sin \Phi c \quad (36)$$
$$l.t. = xc - S.T. \cos \Theta s \quad (37)$$
$$\text{Total length of curve: T.S. to S.T.} = 2Ls + 100\ \Delta c/ Dc \quad (38)$$

4.3.2. Notations:

Ls: minimum length in meters of the spiral, T.S. to S.C. or S.T. to C.S
C: rate of change in centripetal acceleration= (0.3-0.6) m / sec^2 / sec
Rc: radius of the circular curve
Ts: tangent distance.
P: offset distance from tangent to the P.C. of the circular curve produced.
Δ: intersection and central angle of the entire curve.(founded from survey)
k: distance from T.S. to P.C. along tangent.
Es: external distance.
xc,yc: coordinates from T.S. to S.C.& S.T. to C.S.
Θs: spiral angle at S.C. or C.S.
Θ: spiral angle at any point on spiral.
L: length of spiral, from T.S. to any point on the spiral.
Dc: degree of circular curve (arc definition).
D: degree of curve at any point on spiral.
Lc: length of circular curve, S.C. to C.S.
Δc: intersection & central angle of circular curve.
L.C.: long chord of spiral transition.
Φc: deflection from tangent at T.S. to S.C.
Δ: intersection & central angle of entire curve.
c: correction no. for Φ when Θ> 20°
Φ: deflection from tangent at T.S., S.T. or any point on spiral to any other point on spiral.
x,y: coordinates from T.S. or S.T. to any point on spiral.
L.T.: long tangent.
S.T.: short tangent.
P.I.: point of intersection between 2 straight lines, (found from survey).
T.S.: point of the beginning of the spiral, tangent to spiral.
S.C.: point of the beginning of the circular curve and end of the first spiral, spiral curve point.
C.S.: point of the end of the circular curve and beginning of the second spiral, curve spiral point.
S.T.: point of the end of the spiral, spiral to tangent.
L_{tc}: length of the 2 transition curves and circular curve.

Note: the degree of curvature varies directly as the length; from zero curvature at T.S. to the maximum of Dc at the S.C. the spiral departs from the circular curve at the same rate as from the tangent.
Note: at the P.C. the spiral approximately bisects P.

4.3.3 How to layout the stations:
1 – By x and y for each station from T.S.
2 – by Φ and the c_Φ measure of each station from T.S.

4.4. Excel table for the equations:

Table									
Δ (degrees)		$R_{c\ (m)}$		$L_{s(m)}$		$V_{km/hr}$		s %	
$\Theta_{s(degrees)}$ =		$\Theta_{s(radians)}$		X_c =		yc =		P =	
k =		T_s =		E_s =		Δ_c =		D_c =	
L_c =		L_{tc} =		l.t. =		s.t. =		y_{lt} =	

Table (input data)									
Δ (degrees)	**50.6500**	$R_{c\ (m)}$	**1000**	$L_{s(m)}$	**125**	$V_{km/hr}$	**110**	s %	**3.75**
$\Theta_{s(degrees)}$ =		$\Theta_{s(radians)}$		X_c =		yc =		P =	
k =		T_s =		E_s =		Δ_c =		D_c =	
L_c =		L_{tc} =		l.t. =		s.t. =		y_{lt} =	

Table (the information obtained)									
Δ (degrees)	**50.6500**	$R_{c\ (m)}$	**1000**	$L_{s(m)}$	**125**	$V_{km/hr}$	**110**	s %	**3.75**
$\Theta_{s(degrees)}$ =	3.5810	$\Theta_{s(radians)}$	0.0625	X_c =	124.95	yc =	2.60	P =	0.65
k =	62.50	T_s =	536.04	E_s =	107.04	Δ_c =	43.4880	D_c =	5.7296
L_c =	759.01	L_{tc} =	1009.01	l.t. =	83.34	s.t. =	41.69	y_{lt} =	0.77

There is other Excel sheets for circular curve equations and x and y for both transition and circular curves.

References

A Policy on Geometric Design of Highways and Streets. 2011, published by American association of the state highway and transportation officials, Washington D.C.

Orhan Baykal, Ergin Tari & Muhammed Sahin. 1997. New Transition Curve Joining Two Straight Lines. Journal of Transportation Engineering 1997.123: 337-345.

Elwyn E. Seelye. 1968. Design Data Book for Civil Engineers. John Wiley & Sons, Inc. Third Edition.

Thomas F. Hickerson. 1959. Route Surveys and Design. McGraw-Hill Book Company, Inc. Forth Edition