MAXIMUM ALLOWABLE FLOW IN STREETS

BUREAU OF ENGINEERING
City of Los Angeles

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OFFICE STANDARD No. 118
DRAINAGE SYSTEMS ENGINEERING DIVISION
1977
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I. ACKNOWLEDGMENT

The criteria and charts for the application of the momentum equation to the allowable depth of flow in streets were developed by Mr. Irving R. Cole, Division Engineer, Drainage Systems Engineering Division, deceased.

II. INTRODUCTION

The total force of flowing water can create havoc by moving all in its path and causing erosion. Property damage may result from street overflow, but even if water can be contained within the street, the same problems may be created if the velocities are high. To minimize these conditions, studies have indicated that the momentum of storm flows should not exceed that which occurs when a street is full to curb height on a slope of two percent.

The objectives of this Office Standard are:

a) To provide design criteria to determine the maximum allowable flow in streets,

b) To provide ready reference charts to determine the maximum allowable capacity, depth of flow, and momentum of standard street widths.

c) To provide a method to determine the maximum allowable flow in streets with superelevation.

The use of the charts is limited to standard streets with no superelevation or crossfall. For streets with superelevation or crossfall, the street cross-section must be plotted from survey data or plan elevations and the depths and quantities of flow must be calculated as shown herein.

The standard streets used herein have the following roadway widths: 28', 30', 32', 34', 36', 40', 44', 60', 64', 66', 80', and 84'. For other street widths, refer to the Standard Plan "Standard Street Dimensions".
III. NOTATIONS

A  Cross-sectional area of flow (sq. ft.)

d  Depth of flow at curb (ft.)

E  Superelevation of street (ft./ft.)

e  Superelevation of water surface (ft./ft.)

G  Gravity acceleration (32.2 ft./sec.$^2$)

H  Crown height (ft.)

N  Manning's coefficient of friction

P  Wetted perimeter (ft.)

Q  Discharge (cfs)

R  Hydraulic radius (A/P)

$R_C$  Radius of curvature (ft.) to center line of street

$R_{CW}$  Radius of curvature (ft.) to center of water area

S  Slope (ft./ft.)

V  Velocity of flow (ft./sec.)

W  Width of street between curbs (ft.)

W  Horizontal width of water surface (ft.)

Xf  Street crossfall (ft.)

Z  Parkway width (ft.)
IV. DESIGN CRITERIA

A. General:

Where the longitudinal street slope is 2% or less, the depth of flow shall not exceed curb height (usually 8") for a storm of ten-year frequency.

Where the longitudinal street slope exceeds 2%, the depth and quantity of flow shall be reduced so that the calculated momentum of street flow \((QV/g)\) shall not exceed the value of the momentum for flow at curb height on a slope of 2% (limiting value).

The depth of flow shall be further limited for hillside streets, canyon streets, and superelevated streets as shown below.

(Refer to Sections G051.4, G111, and G222 of the Storm Drain Design Manual.)

B. Hillside Streets:

The maximum depth of flow shall not exceed curb height for a storm of 50-year frequency.
C. Canyon Streets:

The maximum depth of flow in canyon streets where the watercourse is eliminated shall not exceed property line height for a storm of 50-year frequency.

D. Superelevated Streets:

The maximum depth of flow for superelevated hillside streets shall not exceed curb height at the lower property line for a storm of 50-year frequency.

The maximum depth of flow for superelevated canyon streets shall not exceed the height of the lower property line for a storm of ten-year frequency.

The maximum depth of flow for other superelevated streets shall not exceed the height of the lower property line with no overflow for a storm of 50-year frequency.

The superelevation of the water surface shall be taken into consideration in computing the depth of flow in superelevated streets. (See problem on page 10.)
V. STREET FLOW DETERMINATION

A. Calculation of Capacity and Momentum:

1. For street slopes up to 2%, the maximum street capacity to curb height is calculated as follows:

\[ Q = \frac{1.486}{n} AR^{2/3} S^{1/2} \]

where \( n = 0.013 \), \( S \) = street slope, \( R = A/P \), \( A \) = cross-sectional area (see below for street cross-sectional areas), and \( P \) = wetted perimeter.

2. For street slopes greater than 2%, the maximum street capacity is determined as follows:

\[ Q = \frac{1.486}{n} AR^{2/3} S^{1/2} \]; \quad \text{Momentum} = \frac{QV}{g} = \frac{Q^2}{Ag} \]

a) Calculate the \( Q \) and momentum for a slope of 2% at curb height.

b) Calculate the \( Q \) and momentum for slopes up to 15% at various depths and plot "\( Q \) vs \( d \)" and "\( QV/g \) vs \( d \)" curves. (See Chart C.)

c) Spot \( QV/g \) value for 2% slope on "\( QV/g \) vs \( d \)" curve and find depth (\( d \)) for the actual slope. Spot \( d \) value on "\( Q \) vs \( d \)" curve and find \( Q \). This \( Q \) is maximum allowable capacity for that street on that slope.

B. Calculation of Cross-Sectional Area:

The street cross-sections given below, except the superelevated cross-section, are parabolic between edge of gutters with a crown height (\( h \)) equal to 0.006 \((W-4) + 0.10\). Superelevated cross-sections have a straight grade between edge of gutters. Normal curb height is 8"; normal gutter width is 2'; normal gutter depth is 1½". The wetter perimeter is assumed as the horizontal width of the water surface plus the depth at each curb.
Street cross-sectional areas are determined as follows:

1. No crossfall - depth between crown and top of curb:

\[ A = A_1 + A_2 + A_3 \]
\[ A_1 = 2(2) \left[ \frac{d + (d - 0.12)}{2} \right] \]
\[ A_2 = (W - 4)(d - h - 0.12) \]
\[ A_3 = \frac{1}{3}(W - 4)(h) \]

or

\[ A = W(d) - \frac{2}{3}(W - 4)(h) - (W - 2)(0.12) \]

2. No crossfall - depth below crown:

\[ A = 2(A_1 + A_2) \]
\[ A_1 = \left[ \frac{d_1 + (d_1 - 0.12)}{2} \right] 2 \]
\[ A_2 = \left( \frac{d_1 - 0.12}{2} \right) \left( \frac{W}{2} - 2 - \frac{L}{2} \right) \]

or

\[ A = Wd_1 - \frac{2}{3}(W-4)(h) - (W - 2)(0.12) + \frac{2}{3}(L)(x) \]
3. Crossfall - depth above crown:

\[ A = A_1 + A_2 + A_3 + A_4 \]

\[ A_1 = \left( \frac{d_1 + d_1'}{2} \right)^2 = d_1 + d_1' \]

\[ A_2 = \left( \frac{d_1' + d_3}{3} \right) \left( \frac{W - 4'}{2} \right) \]

\[ A_3 = \left( \frac{d_3 + d_2'}{3} \right) \left( \frac{W - 4'}{2} \right) \]

\[ A_4 = \left( \frac{d_2' + d_2}{2} \right)^2 = d_2' + d_2 \]

where \( d_1' = d_1 - .12 \) and \( d_2' = d_2 -.12 \)

\[ d_2 = d_1 - XF \]

\[ d_3 = d_1' - \frac{XF}{2} - h \]

4. Crossfall - depth below crown:
MAXIMUM ALLOWABLE FLOW IN STREETS

\[ A = A_1 + A_2 + A_3 + A_4 \]

\[ A_1 = \left( \frac{d_1 + d_1'}{2} \right)^2 = d_1 + d_1' \]

\[ A_2 = \frac{d_1' w_1}{3} = \frac{(d_1')^2}{3S_1} \]

\[ A_3 = \frac{d_2' w_2}{3} = \frac{(d_1')^2}{3S_2} \]

\[ A_4 = \left( \frac{d_2' + d_2}{2} \right)^2 = d_2' + d_2 \]

where \( d' = d - .12 \)

\[ w_1 = \frac{d_1'}{S_1} \]

VI. SUPERELEVATED STREETS

Street flow on superelevated streets has a water surface that is also superelevated, but usually to a lesser degree than the street. Therefore, it is anticipated that the street flow will concentrate on the low side of the street. The critical cross-section is at maximum superelevation, providing the curve is of sufficient length to maintain stable curve flow.

The variables which affect the rate of superelevation of the street surface (E) and the water surface (e) are the street design speed, center line radius, street slope and the radius at the center of water area. A trial and error solution is required to determine the flow cross-sectional area of a superelevated street.
MAXIMUM ALLOWABLE FLOW IN STREETS

SAMPLE PROBLEM

Known: Street slope, property line and roadway widths, and design speed.

Derived from Special Order (Addendum): Horizontal Curve superelevation rate (E) and street center line radius (R_c).

Find: Maximum allowable street capacity on curve.

1. Plot street cross-section with superelevation (E).
   
   ![Diagram of street cross-section with superelevation](image)

2. Calculate water surface superelevation (e).

   \[ e = \frac{v^2}{gR_{cw}} \quad \text{where} \quad V = \frac{QV}{g} \]

   Assume \( R_{cw} = R_c - \frac{W}{4} \)

   Determine velocity from \( QV/g \) and \( Q \) charts for applicable street width and slope.
3. Plot water surface (from R) and calculate w

\[ w = \frac{d'}{E - e} \]

By trial and error, adjust \( R_{cw} \) (formula below) and recalculate \( e \) and \( w \) until values agree. (\( R_{cw} \) at center of water area.)

\[ R_{cw} = R_c - \left( \frac{w+2}{2} \right) \]

4. Calculate water cross-sectional area.

\[ A = A_1 + A_2 + A_3 \]

where

\[ A_1 = \frac{d'' - 2}{2}, \]

\[ A_2 = 2 \left( d + \frac{d''}{2} \right) + \frac{d'}{2}, \]

and

\[ A_3 = \frac{d' \cdot w}{2} \]

5. Calculate maximum capacity (Q) for superelevated street.

\[ Q = AV \]

6. Compare superelevated street Q to non-superelevated street Q. The smaller Q is the maximum allowable flow in the street.
OFFICE STANDARD NO. 118
MAXIMUM ALLOWABLE FLOW IN STREETS
STORM DRAIN DESIGN DIVISION BUREAU OF ENGINEERING
OCTOBER 1969

CAPACITY AND MOMENTUM
FOR A 32' ROADWAY
CHART E
DEPTH OF FLOW ABOVE GUTTER LINE (FT.)

CAPACITY - Q (c.f.s.)

DEPTH OF FLOW ABOVE GUTTER LINE (FT.)

MOMENTUM - \( QV/g \)

OFFICE STANDARD NO. 118
MAXIMUM ALLOWABLE FLOW IN STREETS
STORM DRAIN DESIGN DIVISION  BUREAU OF ENGINEERING
OCTOBER 1969

DESIGNED BY
R.G.C.

CALCULATED BY
R.M.G.B.

DRAWN BY
J.W.B.

CAPACITY AND MOMENTUM FOR A 44' ROADWAY
CHART 1
HIGHWAYS

MAJOR HIGHWAY
86' roadways in 10' dedications are required on all "Federal Aid Secondary" and in certain cases where side by side turning lanes are necessary.

SECONDARY HIGHWAY
Standard sections with a 70 - foot roadway in a 90 - foot right of way shall be provided on the approaches to Major and Secondary Highways.

SECONDARY HIGHWAY
For use on existing streets of 86 - foot dedication. Not to be used for new streets.

SECONDARY HIGHWAY
For use on existing 80 - foot streets or minor streets where setback lines have been established to 80' feet over long period of time. Not to be used for new streets. (66' curb to curb may be required where light pedestrian traffic is anticipated.)

STANDARD FLARE SECTION
Plane sections will be required at intersections with Major and Secondary Highways and other important streets.

FRONTAGE ROADS - ALONG FREEWAYS
For use in State Highway Freeway construction.

ALLEYS

STANDARD TURNING AREA

MINIMUM TURNING AREA

STANDARD CROSS - SECTION

STANDARD CUT - CORNERS

NOTE: Dimensions shown hereon are not to scale.

STANDARD STREET CONDITIONS
1. Sidewalk widths for local streets shall be the minimum shown hereon. Greater widths, up to full width between curb and property line, with tree wells, shall be required where commercial, industrial, and multiple residential frontage, schools, areas of heavy pedestrian traffic or other special circumstances indicate the need.
2. Except for special conditions or as otherwise provided, sidewalk shall be placed as close to the property line as possible.
3. Where sidewalk is constructed adjacent to the curb it shall have a minimum width of 6.5 ft. exclusive of curb thickness except for non - primary hillside streets.
4. Where sidewalk is constructed on the fill or low side of a hillside street, a Berm will be required on private property.
5. Easements may be required in addition to the widths shown hereon, where necessary for the installation of public utilities.
6. Fifty - foot curb radii shall be provided for cul-de-sacs in industrial areas.
7. Private street development shall conform to the standard street dimensions shown on this sheet.

STANDARD PLAN

D - 22549

SUPERSEDES PLAN B - 3695
EFFECTIVE SEPTEMBER 23, 1969

DEPARTMENT OF PUBLIC WORKS
BUREAU OF ENGINEERING
CITY OF LOS ANGELES

STANDARD STREET DIMENSIONS

DESIGNED BY
S F
SUBMITTED: DECEMBER 27, 1968
APPROVED: JULY 25, 1968

DRAWN BY
I V J.
BUREAU OF ENGINEERING
APPROVED: JULY 25, 1968

CHECKED BY
A F L.
PARKS CITY ENGINEER
APPROVED: AUGUST 4, 1968

ADOPTED: MARCH 27, 1969
CITY PLANNING COMMISSION

APPROVED: AUGUST 6, 1968
DIRECTOR OF PLANNING

APPROVED: AUGUST 6, 1968
DIRECTOR OF PLANNING

APPROVED: JUNE 1, 1968
CITY ENGINEER

APPROVED: JUNE 1, 1968
CITY ENGINEER
Horizontal curves should, wherever possible, have large enough radii to permit safe travel at the desired design speed without superelevation. There will be many cases, however, where shorter radii than those requiring no superelevation will provide a more economical and advantageous alignment. Such curves will require superelevation in order to permit safe operation at the design speed. Superelevation will also provide a more uniform speed in all lanes and will eliminate abrupt changes in the maximum safe speed at reversing curves.

The policy of the Bureau of Engineering regarding superelevation shall be as set forth in the attached five sheets. Division and District Engineers are instructed to follow the policy outlined therein, whenever necessary, to meet the design speed for the particular class of street involved. A brief description of the five sheets follows.

1. Side Friction Factors:

The maximum safe side friction factor recommended on the attached chart for use in design varies from 0.09 ft/ft. at 100 m.p.h. to 0.300 ft/ft. at 20 m.p.h. The side friction factor at impending side skid is also shown on the chart. The factor of safety for the design value of \( F \) varies from 3.33 at 100 m.p.h. to 1.67 at 20 m.p.h. The value of \( F \) recommended for design by the American Association of State Highway Officials is also shown on the chart. It is a little more conservative than the recommended value for the Bureau of Engineering.

2. Maximum Safe Speed on Horizontal Curves:

This chart has been prepared from the exact formula for superelevation, using the recommended value of \( F \) for maximum safe speed and rates of superelevation varying from -0.05 ft/ft. to +0.12 ft/ft. This chart shall be used for the solution of all problems concerning maximum safe speed.

3. Superelevation and Superelevation Transition:

The amount of superelevation and the length of the superelevation transition for radii larger than the minimum are shown graphically on this chart. Formulas are given for calculating these values. The method of attaining the maximum superelevation is also shown. On flat grades this recommended method of revolving the pavement surface about the center line will result in sumps on the outer edges of the pavement. In order to avoid this condition, the pavement surface should be revolved about the inside edge rather than the center line. In this case, the transition should be twice as long as the length shown on the chart.
Special Order

4. Minimum Radius and Maximum Transition: Lengths for Limiting Values of $E$ and $F$

This table gives minimum radii and transition lengths with maximum superelevation of 0.06 ft/ft., which is considered to be the desirable maximum for city streets. Minimum radii and transition lengths are also given for zero superelevation. The value for $C$, the rate of increase of the unbalanced centrifugal force in the formula for the length of transition has been taken from the AASHO Policy on Urban Highways. It is noted that the transition length to safely reverse the unbalanced centrifugal thrust is the same for the maximum superelevation, as well as for zero superelevation. This condition results from the fact that the formula for length is based on the maximum allowable unbalanced centrifugal thrust. From this table it is possible to calculate the minimum desirable tangent between reversing curves of minimum radii. Since $2/3$ of the maximum superelevation should be provided at the B.C. and E.C. of the curves, the minimum tangent length is $2/3$ of twice the transition length.

The following table gives minimum tangent lengths between reversing curves:

<table>
<thead>
<tr>
<th>HIGHWAY CLASS</th>
<th>DESIGN SPEED M.P.H.</th>
<th>MINIMUM RADIUS Reversing Curves $E = 0.06$ ft./ft.</th>
<th>MINIMUM RADIUS Reversing Curves $E = 0.00$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Radius Feet</td>
<td>Tangent Feet</td>
</tr>
<tr>
<td>Local Hillside</td>
<td>20</td>
<td>73</td>
<td>96</td>
</tr>
<tr>
<td>Local Flat</td>
<td>25</td>
<td>132</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>212</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>314</td>
<td>135</td>
</tr>
<tr>
<td>Collect</td>
<td>40</td>
<td>443</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>600</td>
<td>168</td>
</tr>
<tr>
<td>Major &amp; Secondary</td>
<td>50</td>
<td>782</td>
<td>186</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>994</td>
<td>219</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>1241</td>
<td>251</td>
</tr>
</tbody>
</table>

5. Design of Horizontal Curves with Superelevation:

This sheet shows a typical example of superelevation design for local hillside streets.

In superelevating curves, consideration must always be given to control of dry weather drainage such as excess lawn irrigation. Run-off resulting from lawn sprinkling in general should not be permitted to flow across the roadway at reversals in the superelevation. This condition can be controlled by constructing a 2-foot gutter on the edge of the superelevated section with a normal 1-1/2-inch rise across the gutter.
### Special Order

The hydraulic capacity of the standard 2-foot gutter on various slopes is as follows:

<table>
<thead>
<tr>
<th>Slope (ft./ft.)</th>
<th>Q (c.f.s.)</th>
<th>Q (g.p.m.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.015</td>
<td>0.230</td>
<td>103</td>
</tr>
<tr>
<td>0.02</td>
<td>0.264</td>
<td>119</td>
</tr>
<tr>
<td>0.04</td>
<td>0.375</td>
<td>168</td>
</tr>
<tr>
<td>0.06</td>
<td>0.459</td>
<td>206</td>
</tr>
<tr>
<td>0.08</td>
<td>0.530</td>
<td>238</td>
</tr>
<tr>
<td>0.10</td>
<td>0.592</td>
<td>264</td>
</tr>
<tr>
<td>0.12</td>
<td>0.650</td>
<td>292</td>
</tr>
<tr>
<td>0.14</td>
<td>0.700</td>
<td>315</td>
</tr>
</tbody>
</table>

To give some idea of how much dry weather run-off these quantities represent, the average 5/8-inch garden hose 75 feet long will discharge approximately 10 g.p.m. under a head of 40 p.s.i. It appears that the standard 2-foot gutter will adequately handle the majority of conditions where dry weather flow might create a problem on superelevated curves.

LYALL A. PARDEE, City Engineer
SUPERELEVATION OF CITY STREETS AND HIGHWAYS

SIDE FRICTION FACTORS

FORMULA

\[
\frac{F + E}{1 - EF} = \frac{V^2}{15R}
\]

E = SUPERELEVATION - FT./FT.
F = SIDE FRICTION FACTOR - FT./FT.
V = VELOCITY - MILES PER HOUR
R = RADIUS - FT.

FACTOR OF SAFETY FOR \( F \) AT MAXIMUM SAFE SPEED

AGAINST SIDE SKIDDING = \( \frac{F \text{ AT IMPENDING SIDE SKID}}{F \text{ FOR MAXIMUM SAFE SPEED}} \)

F.S. AT 100 M.P.H. = \( \frac{0.30 \times 3.33}{0.09} \)
F.S. AT 20 M.P.H. = \( \frac{0.50}{0.30} \times 1.67 \)

SIDE SKID IMPENDING

- • - NOBLE & STONEY, HIGHWAY RESEARCH BOARD 1940
- □ - MOYER & BERRY, ASPHALT HIGHWAY RESEARCH BOARD 1940
- ▲ - MOYER & BERRY, CONCRETE HIGHWAY RESEARCH BOARD 1940

MAXIMUM SAFE SPEED

- • - STOICHER, HIGHWAY RESEARCH BOARD BULLETIN
- ♦ - DONALD THOMPSON, UNPUBLISHED PAPER, CITY OF LOS ANGELES

D. Thompson Feb. 1961
SUPERELEVATION FOR CITY STREETS AND HIGHWAYS

MAXIMUM SUPERELEVATION = 0.06 FT./PT.

R = RADIUS - FT.

SUPERELEVATION TRANSITION

MAX. L = 47.2(Fv)(V)
        C
F = MAX. SAFE SIDE FRICTION - FT./FT.
C = RATE OF CHANGE OF F. FT./SEC.³
SEE TABLE 1
FOR RADII LARGER THAN
MINIMUM, \( L_R = \frac{(\text{MAX. } L)}{\text{MIN. } R} \)
\( L \) SHOULD BE A MULTIPLE OF 3
TRANSITION PROFILE

CROSS SECTIONS
PAVEMENT REVOLVED ABOUT \( \theta \)

SUPERELEVATION

\[ V^2 \left[ 1 - \frac{(\text{MAX. } E)}{\text{MIN. } R} (F_v) \right] \]
\[ \text{MIN. } R = \frac{15}{\text{MAX. } E + F_v} \]
MAX. E = 0.06 FT./PT.
FOR RADII LARGER THAN
MINIMUM, \( E = \frac{(\text{MIN. } R)(\text{MAX. } E)}{R} \)
\( F_v \) = MAXIMUM SAFE F FOR DESIGN SPEED. SEE TABLE 1.

D. Thom. : Feb. 1961
**TABLE 1**

**MINIMUM RADIUS & MAXIMUM TRANSITION LENGTH FOR LIMITING VALUES OF E & F**

**FORMULAS**

1. **Superelevation**
   
   \[ E + F = \frac{V^2}{1 - E F} \]

2. **Length of Superelevation Transition**
   
   \[ L = \frac{47.2 VF}{C} \]

   \[ E = \text{Superelevation Slope - FT./FT.} \]

   \[ F = \text{Side friction factor or unbalanced thrust - FT./FT.} \]

   \[ V = \text{Velocity - Miles per hour} \]

   \[ R = \text{Radius - FT.} \]

   \[ L = \text{Length of Superelevation Transition - FT.} \]

   \[ C = \text{Rate of Increase of F in FT./SEC.}^3 \]

<table>
<thead>
<tr>
<th>Design Speed M.P.H.</th>
<th>Maximum E</th>
<th>Maximum F</th>
<th>E + F</th>
<th>1 - EF</th>
<th>Minimum Radius Feet</th>
<th>C FT/SEC³</th>
<th>Maximum Transition Feet</th>
<th>Highway Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.06</td>
<td>0.300</td>
<td>0.360</td>
<td>0.982</td>
<td>73</td>
<td>4.00</td>
<td>71</td>
<td>SPECIAL</td>
</tr>
<tr>
<td>25</td>
<td>0.06</td>
<td>0.252</td>
<td>0.312</td>
<td>0.985</td>
<td>132</td>
<td>3.75</td>
<td>79</td>
<td>HILLSIDE</td>
</tr>
<tr>
<td>30</td>
<td>0.06</td>
<td>0.221</td>
<td>0.281</td>
<td>0.987</td>
<td>212</td>
<td>3.50</td>
<td>90</td>
<td>FLAT LOCAL</td>
</tr>
<tr>
<td>35</td>
<td>0.06</td>
<td>0.197</td>
<td>0.257</td>
<td>0.988</td>
<td>314</td>
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<td>0.223</td>
<td>0.990</td>
<td>600</td>
<td>2.75</td>
<td>126</td>
<td>MAJOR &amp; SECONDARY</td>
</tr>
<tr>
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<td>0.151</td>
<td>0.221</td>
<td>0.991</td>
<td>782</td>
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<td>143</td>
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</tr>
<tr>
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<tr>
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<td>0.993</td>
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<td>2.00</td>
<td>187</td>
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**Superelevation on Curves with Radii Larger than the Minimum Should Vary Inversely with the Radius.**

\[ E_r = \frac{\text{MIN. R}}{R} \times \text{MAX. E} \]

**Length of Transition for Curves with Radii Larger than the Minimum Should Vary Inversely with the Radius.**

\[ L_r = \frac{\text{MIN. R}}{R} \times \text{MAX. L} \]

**Transition Length Should Be a Multiple of 3. Superelevation at B.C. & E.C. Should Be \( \frac{2}{3} \) of Maximum.**

D. Thompson Feb. 1961
DESIGN OF HORIZONTAL CURVES
WITH SUPERELEVATION

TYPICAL EXAMPLE

Local Hillside Street
Design Speed - 25 MPH
Minimum Radius - 132 Ft. (Table 1)
Maximum Superelevation - 0.06 Ft./Ft.
Width of Roadway - 30 Ft.
Tangent Crown - 0.25 Ft.
Alignment - Reversing Curves with
Radii of 132' and 200' separated
by a Tangent of 90'.

FROM TABLE 1 FOR DESIGN SPEED
OF 25 MPH

\[ R_1 = 132 \text{ Ft.} \]
\[ E_1 = 0.06 \text{ Ft./Ft.} \]
\[ L_1 = 81 \text{ Ft. (multiple of 3)} \]
\[ X = \text{Fall at Max. E =1.80 Ft.} \]

\[ R_2 = 200 \text{ Ft.} \]
\[ E_2 = 0.04 \text{ Ft./Ft. = 0.06 \[ \frac{132}{200} \]} \]
\[ L_2 = 54 \text{ Ft. = 81 \[ \frac{132}{200} \]} \]
\[ X = \text{Fall at Max. E =1.20 Ft.} \]

Min. Tangent = \[ \frac{2}{3} (81+54) = 90 \text{ Ft.} \]

Provide \[ \frac{2}{3} \] of Max. E at B.C.
and E.C. of curves.

Factor of Safety against side
skid for 132 Ft. \[ \epsilon \] Radius is:
\[ \text{F.S.} = \frac{31.5 \text{ MPH}}{25.0 \text{ MPH}} = 1.26 \]

D. Thompson  b. 1961