TO ALL:  DEPUTY ENGINEERS
DIVISION ENGINEERS
DISTRICT ENGINEERS

SUBJECT:  STREET DESIGN STANDARDS

1. ROADWAY CROWN

A parabolic cross section shall be used on all streets with certain exceptions noted below.

Height of the crown shall be calculated by the formula

\[ C = 0.006W + 0.10 \]

where

\[ C = \text{Crown in ft.} \]
\[ W = \text{Roadway width (curb to curb) less width of gutters.} \]

This crown will provide a slope of 2.5% in the 10 ft. lane immediately adjacent to the outside edge of the gutters.

On streets having a continuous curved alignment with minimum tangents between reversing curves, the "tent" section may be substituted for the parabolic section. The pavement surface in this case shall be constructed on a straight grade between the center line elevation and the outer edge of the gutter.

The minimum slope for tangent alignment using the tent section shall be 1.5%.

2. CONCRETE GUTTER

The normal width for concrete gutter is 2 ft. Integral curb and 2 ft. concrete gutter shall be required on new construction. Exceptions are permitted when joining existing narrower gutters or where conditions warrant a wider gutter.
3. PROFILE GRADES
   
   (a) Streets
   Grades shall be shown for the top of the curb on each side of the street and for the center line of the roadway.

   (b) Alleys
   Grades shall be shown for the header on each side of the alley and for the flow line of the longitudinal gutter.

4. PAVEMENT ELEVATIONS
   
   The cross section shall be defined by elevations at construction lines approximately 10 ft. apart (8 ft. to 12 ft.). Elevations may either be shown on the plans or defined by ordinates or "T" sections on a typical cross section.

LYALL A. PARDEE, City Engineer

s/ LYALL A. PARDEE

DT:fs:11
Exec.
Red: 10-13-66
(b) Curbs both side of streets.
(c) 5 ft. sidewalk on both sides of street.
(d) One ft. concrete gutter 6" thick on grades of less than 0.4 per cent on residential streets.
(e) Two ft. concrete gutters 8" thick on major streets.
(f) Guard rails where required.

8. Standards of Design.

(a) Minimum curb grade 0.2%
   Maximum curb grade as previously noted.
(b) Standard sidewalk slope 2.0 %
   Maximum sidewalk slope 6%
(c) One foot concrete gutter rise 1 inch.
   Two foot concrete gutter rise 1½ inch.
   Minimum width of cross gutters 2 ft.
(d) Changes in longitudinal grades not to exceed 1.25%.

(e) Maximum crown used on roadway is 4 times the 8th of the pavement between curbs where gutters do not exist.

(f) T sections and numbered sections are used to denote crown on streets. T sections are in inches. Crown sections are in feet.

(g) Maximum desirable cross fall on streets 8%.
(h) Maximum rise used out of cross gutters.
(i) Minimum curb radii 15 ft. and maximum radii 25 ft. (without storm drain.

(j) Standard curb face 8". May decrease to 6" or increase to 10" in special cases.

(k) Expansion joints and contraction joints.

9. In establishing curb grades keep in mind the contour of the ground in and around the area being developed.

(a) Drainage
(b) Desirable to have at least 6" cut in grade.
(c) Sanitary Sewers
(d) Building sites.
1.

**STANDARD FOR WEIGHT AND SYMBOLISM OF LINES FOR CONSTRUCTION PLANS.**

**LINE WEIGHT No. 1**

<table>
<thead>
<tr>
<th>Property Lines Existing</th>
<th>Standard</th>
<th>Property Lines Proposed</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>2H</td>
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**LINE WEIGHT No. 2**

<table>
<thead>
<tr>
<th>Curb Lines Existing</th>
<th>Proposed</th>
<th>Proposed Under Separate Improvement Or Future Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3H</td>
<td></td>
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</tbody>
</table>

**LINE WEIGHT No. 3**

<table>
<thead>
<tr>
<th>Existing Sidewalk Or Gutter</th>
<th>Proposed Sidewalk Or Gutter</th>
<th>Street Railway Right Of Way Lines</th>
<th>Construction Note Leaders</th>
<th>Boundaries Of Proposed Pavement Or Other Improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

**LINE WEIGHT No. 4**

<table>
<thead>
<tr>
<th>Center Lines</th>
<th>Lines Indicating Straight Grade Between Elev.</th>
<th>Cross Section Lines</th>
<th>Dimension, Elevation Or Other Leader Lines Except Construction Note Leaders</th>
<th>Flow Line Of Cross Gutters</th>
<th>Radial Lines (At B.C., E.C. &amp;c)</th>
<th>Railway Tracks - Existing Or Proposed</th>
</tr>
</thead>
<tbody>
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- *Use Either Straight Edge Or French Curve*

**NOTE:**

For pencil drawings on tracing paper use an "H" or a "2H" pencil for line weight No. 1, "3H" or "4H" for weights Nos. 2 & 3 and "5H" or "6H" for weight No. 4.
2.

STANDARD FOR WEIGHT AND SYMBOLISM

OF LINES FOR CONSTRUCTION PROFILES (FINISHED DRAWINGS ON CLOTH)

1. The heaviest profile line shall be the proposed curb grade which shall be weight No. 2 as shown on standard for lines on plans. The line shall be broken at every grade change by a small circle, thus -o-o-o-o-.

2. Existing curbs, building floors and ground lines shall be solid lines weight No. 3.

3. All profile lines of other existing improvements shall be dotted or broken lines. Weight No. 3 per above standard.

Note:- Profiles of all existing improvements shall be ruled lines. Ground lines to be drawn freehand.

Instructions to be used in working up and checking construction plans.

Work Sheet - Profiles and Cross Sections.

1. Cross Check level notes - (to be done by man who works up job.)

2. Plot profiles and cross sections - checker to make detailed check.

(a) Existing improvements to be shown on profile by ruled dotted or ruled broken lines (black pencil or black ink only). On cross sections, surface of existing pavement shall be drawn using French Curve or spline and shall be dotted or broken line. Profiles and cross sections shall always be plotted using the ratio of 10 horizontal to 1 vertical such as 1" = 8.0' horizontal to 1" = 0.8' vertical or 1" = 4.0' horizontal to 1" = 0.4' vertical.

(b) Profiles of North and South streets shall be plotted with North end of street at right hand end of work sheet. West side of street shall be plotted nearest to top of sheet.

(c) Profiles of East and West streets shall be plotted with East end of street at right hand end of work sheet. North side of street shall be plotted nearest top of sheet.

(d) All cross sections shall be plotted looking North or West.

3. Lay grades on profiles and show same on cross sections - checker shall check in detail.

(a) When plotting proposed "T" sections - plot both ends, both quarter points and center points. (See standard plan No. 29781).

(b) All proposed grades shall be shown by solid lines.

(c) Free use of colors to clarify work sheet is recommended.
Plan

1. General Instructions.
   (a) Letter "i" shall be dotted.
   (b) Place period after abbreviations (see Std. Plan B-3495 for proper abbreviations used by City and State plans for abbreviations used by State.)
   (c) Use symbol for feet or inches on all dimensions, thus 4', 8".
   (d) Show all dimensions except curb face in feet and hundredths of feet, thus 4.66'.
   (e) Show all dimensions under one foot, thus 0.66'.
   (f) Follow Standard for weight and symbolism of lines for construction plans in making all drawings for constructions.
   (g) Make drawings accurate - do not guess at right angles for section lines or dimensions leaders. Use triangles or other mechanical means.
   (h) When indicating "T" Sections - both ends of sections must be definitely located by dimensions or stations, and an elevation must appear at each end of section.
   (i) Use guide lines for all lettering.

2. North Point - trace or copy North Point from Standard Plan, 29068. Use small North Point on small drawings, and large one on large drawings. If drawing is extremely small or extremely large, reduce or enlarge standard North Point in proportion, but do not change style. North Point shall always point upward or to your right.

3. Scale - show plan scale near North Point.

4. Title
   (a) For ink titles use latest standard plan as guide.
   (b) For pencil titles use latest standard plan but reduce height of letters approximately 20% to compensate for lighter weight of lines.
   (c) Limits of work shall always read from North to South or from East to West.

5. Reference.
   (a) List field book numbers and pages used.
   (b) Show number of city profile by which adjoining existing improvements were constructed.

6. Alignment
   (a) All calculations shall be made by man who works up job and
6. Alinement. Continued

(b) For curve data show on plan the radius, (R); Central Angle (\(\Delta\)) Length of arc, (L) and the tangent (T).

7. Stationing - All stations shown on plan shall be checked by checker and plotting of plan shall be checked using protractor and scale.

8. Elevations.

(a) All elevations including finished surface of pavement, sidewalks, etc, shall be checked.

(b) All "T" sections shall be checked.

9. Construction and removal notes. - Checker shall see that all necessary construction and removal notes are shown on plan and that they clearly indicate the work to be done. Do not cross leaders from construction notes over each other.


(a) See that all join points are clearly indicated by station or dimension.

(b) Curb joins shall be marked - join curb (elevation).

(c) Flow line joins shall be marked - join F.L. (elevation)

(d) Where possible paving join points shall be marked - Join (elev

11. Miscellaneous points to remember.

(a) When placing new curb where sidewalk is existing, check to see that sidewalk is above the new curb grade allowing a minimum grade across the sidewalk area or parkway of 1% and a maximum of 6%, otherwise replace the sidewalk.

(b) Indicate profile numbers on all intersecting streets shown and direction and rate of grade.

(c) Indicate type of existing pavement at or near join points with new pavement.

(d) When replacing an existing pavement the new pavement shall be the same type and thickness as the existing pavement or as ordered by the City Council, Department Head or others in authority.

(e) It costs money to remove and reconstruct existing improvements so avoid removing so far as possible, but remove any existing improvements necessary to make a good job.

(f) Don't suggest a change in design unless it is a distinct improvement.

(g) Don't change elevations or dimensions for 0.02' or less.
11. Misc. points to remember. Continued

(b) Checkers do not change anything on a plan without consulting the man who worked up the job. In event of a dispute get opinion of leader.

CHECK LIST

1. Plotting of existing improvements on profiles.
2. Plotting of existing improvements on cross-sections.
3. Proposed Grades on profiles.
   (a) Are vertical curves long enough - i.e. - is the difference between successive rates of grade less than 1.25% (b) Does new grade fit any existing sidewalk which is not being removed? (c) Does new grade fit improvements on abutting private property? (d) If grade is for pavement cover job, is there sufficient cover? (e) If there is considerable fall around any curb return, has a sidewalk grade been figured for the property line?
4. Proposed grades on cross-sections.
5. Layout of plan (use scale and protractor).
   (a) Street widths. (b) Curb line distance from property line. (c) Location and type of existing improvements. (d) Proposed improvements. (e) Orientation of North Point.
7. Calculations for new alignments.
8. Transfer of alignment data from calculation sheets to plan.
9. Transfer of elevations and curb faces from work sheet to plan.
11. Joins points for all new improvements.
12. Construction notes.
13. Removal notes.
14. Field Book and Profile References.
15. North Point.
16. Scale.
17. Title (a) Location and limits of work. (b) Job title and number.
18. Work stamp; designed by &c.
19. City Engineer's approval stamp.
20. Acceptance Stamp.
<table>
<thead>
<tr>
<th>C.F. - Max 9&quot;</th>
<th>MID 4&quot;</th>
</tr>
</thead>
</table>

**EXCEPTION:** CAN ENCLOSE ON THESE LIMITS FOR SHORT REACHES.

**F.L. GRADES**

- 120% Min
- 15% Abs. Minimum

**Note:** If less than 120% grade put note on plan.

**Have St. Maint Require**

Grades from survey @ 12½ instead of 25.
SPECIAL ORDER

TO ALL: DEPUTY ENGINEERS
DIVISION ENGINEERS
DISTRICT ENGINEERS

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Height of the crown shall be calculated by the formula

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This crown will provide a slope of 2.5% in the 10 ft. lane immediately adjacent to the outside edge of the gutters.

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LYALL A. PARDEE, City Engineer

/s/ LYALL A. PARDEE
TO ALL: Deputy Engineers
Division Engineers
District Engineers

Subject: Policy on Vertical Curves

Vertical curves shall be of sufficient length to provide adequate sight distance and comfortable vertical acceleration for the assumed design speed of the highway. Except for certain cases noted below, a minimum stopping sight distance at least equal to the safe stopping distance shall be provided on all curves.

I NOTATION

L = Length of vertical curve in feet.
A = Algebraic difference in grades in per cent/100.
S = Sight distance in feet.
V = Design speed in miles per hour.
D = Safe stopping distance in feet.
d = Distance between grade breaks in feet.
a = Vertical acceleration in feet/sec./sec.
R = L/A = Minimum radius of vertical curve in feet.

II SAFE STOPPING DISTANCE

The safe stopping distance shall conform to the recommendations of the American Association of State Highway Officials. Safe stopping distance equals the reaction distance (D1) + the braking distance (D2).

\[ D_1 = 1.47 \times V \times (3.75-0.025V) \]
\[ D_2 = \frac{0.0334V^2}{0.575-0.0025V} \]
\[ D = 1.47 \times (3.75-0.025V) + \frac{0.0334V^2}{0.575-0.0025V} \]

The attached chart gives safe stopping distances for speeds from 20 to 70 miles per hour.

III SIGHT DISTANCE REQUIREMENTS

1. Summit Curves.
   A. Stopping Sight Distance.
      Provide visibility for a 4 inch object at least equal to the safe stopping distance for the design speed of the highway. Height of eye is assumed to be 4.5 feet.
When $S$ is less than $L$, $S = 3.82 \sqrt{\frac{L}{A}}$

When $S$ is greater than $L$, $S = 7.28 + \frac{L}{\sqrt{A}}$

<table>
<thead>
<tr>
<th>Class of Highway</th>
<th>Design Speed M.P.H.</th>
<th>Safe Stopping Distance = Stopping Sight Distance-feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>Secondary</td>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>Collector</td>
<td>40</td>
<td>275</td>
</tr>
<tr>
<td>Local-Flat</td>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>Local-Hillside</td>
<td>25</td>
<td>150</td>
</tr>
</tbody>
</table>

A chart showing length of vertical curve and stopping sight distance for values of $A$ from 0.01 to 0.12 is attached.

B. Summit Curves Adjacent To Intersections.

Summit vertical curves which hide an intersection should be of sufficient length to provide visibility for a vehicle to enter a main highway from the hidden intersection without being overrun by vehicles traveling at normal speed on the main highway. Heights of eye and vehicle are assumed to be 4.5 feet.

When $S$ is less than $L$, $S = 6.00 \sqrt{\frac{L}{A}}$

When $S$ is greater than $L$, $S = \frac{18}{A} + \frac{L}{2}$

<table>
<thead>
<tr>
<th>Class of Highway</th>
<th>Design Speed M.P.H.</th>
<th>Roadway Width Feet</th>
<th>Vehicle Sight Distance at Intersection - Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>50</td>
<td>80</td>
<td>650</td>
</tr>
<tr>
<td>Secondary</td>
<td>50</td>
<td>64</td>
<td>600</td>
</tr>
<tr>
<td>Collector</td>
<td>40</td>
<td>40</td>
<td>450</td>
</tr>
<tr>
<td>Local-Flat</td>
<td>30</td>
<td>36</td>
<td>350</td>
</tr>
<tr>
<td>Local-Hillside</td>
<td>25</td>
<td>28</td>
<td>300</td>
</tr>
</tbody>
</table>

2. Sag Curves.

A. Stopping Sight Distance.

Provide headlight visibility, except on lighted highways, at least equal to the safe stopping distance for the design speed of the highway. The headlight is assumed to be 2.5 feet above the pavement surface with a maximum deviation of the beam above the horizontal of one degree of arc.
(b) Curbs both side of streets.
(c) 5 ft. sidewalk on both sides of street.
(d) One ft. concrete gutter 6" thick on grades of less than 0.4 per cent on residential streets.
(e) Two ft. concrete gutters 8" thick on major streets.
(f) Guard rails where required.

8. Standards of Design.

(a) Minimum curb grade 0.2%
   Maximum curb grade as previously noted.
(b) Standard sidewalk slope 2.07%
   Minimum sidewalk slope 6%
(c) One foot concrete gutter rise 1 inch.
   Two foot concrete gutter rise 1½ inch.
   Minimum width of cross gutters 2 ft.
(d) Changes in longitudinal grades not to exceed 1.25
\[ \frac{w \times 0.000075 \times 22}{w} = 0.06w + 1 \]
(e) Maximum crown used on roadway: 
\[ \frac{w}{w} \times \text{time} \times \text{width} \]
   \[ w = \text{time} \times \text{the width of the pavement between curbs where gutters do not exist} \]
   \[ w = \text{time} \times \text{the width of the pavement between outside edge of concrete gutters where exist.} \]
(f) T sections and numbered sections are used to denote crown on streets. T sections are in inches. Crown sections are in feet.
(g) Maximum desirable cross fall on streets 8%.
(h) 2% maximum rise used out of cross gutters.
(i) Minimum curb radii 15 ft. and maximum radii 25 ft.
   In special cases larger radii may be used.
(j) Standard curb face 8". May decrease to 6" or increase to 10" in special cases.
(k) Expansion joints and contraction joints.

9. In establishing curb grades keep in mind the contour of the ground in and around the area being developed.

(a) Drainage
(b) Desirable to have at least 6" cut in grade.
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(d) Building sites.
1. STANDARD FOR WEIGHT AND SYMBOLISM OF LINES FOR CONSTRUCTION PLANS.

**LINE WEIGHT NO. 1**

PROPERTY LINES EXISTING
PROPERTY LINES PROPOSED

**LINE WEIGHT NO. 2**

CURB LINES EXISTING
" " PROPOSED
" " PROPOSED UNDER SEPARATE IMPROVEMENT
OR FUTURE CONSTRUCTION

**LINE WEIGHT NO. 3**

EXISTING SIDEWALK OR GUTTER
PROPOSED SIDEWALK OR GUTTER
STREET RAILWAY RIGHT OF WAY LINES
CONSTRUCTION NOTE LEADERS
BOUNDARIES OF PROPOSED PAVEMENT OR OTHER
IMPROVEMENTS

**LINE WEIGHT NO. 4**

CENTER LINES
LINES INDICATING STRAIGHT GRADE BETWEEN ELEV.
CROSS SECTION LINES
DIMENSION, ELEVATION OR OTHER LEADER LINES
EXCEPT CONSTRUCTION NOTE LEADERS
PLOW LINE OF CROSS GUTTERS
RADIAL LINES (AT B.C., E.C. &c)
RALLWAY TRACKS - EXISTING OR PROPOSED

* USE EITHER STRAIGHT EDGE OR FRENCH CURVE

NOTE:--
FOR PENCIL DRAWINGS ON TRACING PAPER USE AN "H" OR A "2H"
PENCIL FOR LINE WEIGHT No. 1 "3H" OR "4H" FOR WEIGHTS Nos. 2 & 3
AND "5H" OR "6H" FOR WEIGHT No. 4.
STANDARD FOR WEIGHT AND SYMBOLISM
OF LINES FOR CONSTRUCTION PROFILES (FINISHED DRAWINGS ON CLOTH)

1. The heaviest profile line shall be the proposed curb grade which shall be weight No. 2 as shown on standard for lines on plans. The line shall be broken at every grade change by a small circle, thus: o-0-o-0-o-

2. Existing curbs, building floors and ground lines shall be solid lines weight No. 3.

3. All profile lines of other existing improvements shall be dotted or broken lines. Weight No. 3 per above standard.

Note: Profiles of all existing improvements shall be ruled lines. Ground lines to be drawn freehand.

Instructions to be used in working up and checking construction plans.

Work Sheet - Profiles and Cross Sections.

1. Cross Check level notes - (to be done by man who works up job.)

2. Plot profiles and cross sections - checker to make detailed check.

(a) Existing improvements to be shown on profile by ruled dotted or ruled broken lines (black pencil or black ink only). On cross sections, surface of existing pavement shall be drawn using French Curve or spline and shall be dotted or broken line. Profiles and cross sections shall always be plotted using the ratio of 10 horizontal to 1 vertical such as 1" = 8.0' horizontal to 1" = 0.9' vertical or 1" = 4.0' horizontal to 1" = 0.4' vertical.

(b) Profiles of North and South streets shall be plotted with North end of street at right hand end of work sheet. West side of street shall be plotted nearest to top of sheet.

(c) Profiles of East and West streets shall be plotted with East end of street at right hand end of work sheet. North side of street shall be plotted nearest top of sheet.

(d) All cross sections shall be plotted looking North or West.

3. Lay grades on profiles and show same on cross sections - checker shall check in detail.

(a) When plotting proposed "T" sections - plot both ends, both quarter points and center points. (See standard plan No. 29781).

(b) All proposed grades shall be shown by solid lines.

(c) Free use of colors to clarify work sheet is recommended.
Plan

1. General Instructions.
   (a) Letter "i" shall be dotted.
   (b) Place period after abbreviations (see Std. Plan B-3495 for proper abbreviations used by City and State plans for abbreviations used by State.)
   (c) Use symbol for feet or inches on all dimensions, thus 4", 8".
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4. Title
   (a) For ink titles use latest standard plan as guide.
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   (c) Limits of work shall always read from North to South or from East to West.

5. Reference.
   (a) List field book numbers and pages used.
   (b) Show number of city profile by which adjoining existing improvements were constructed.

6. Alignment.
   (a) All calculations shall be made by man who works up job and shall be checked in detail by checker.
6. Alinement. Continued

(b) For curve data show on plan the radius, (R); Central Angle (Δ)
    Length of arc, (L) and the tangent (T).

7. Stationing - All stations shown on plan shall be checked by checker
    and plotting of plan shall be checked using protractor and scale.

8. Elevations.

(a) All elevations including finished surface of pavement, side-
    walks, &c, shall be checked.

(b) All "T" sections shall be checked.

9. Construction and removal notes. - Checker shall see that all neces-
    sary construction and removal notes are shown on plan and that they
    clearly indicate the work to be done. Do not cross leaders from
    construction notes over each other.


(a) See that all join points are clearly indicated by station or
    dimension.

(b) Curb joins shall be marked - join curb (elevation).

(c) Flow line joins shall be marked - join F.L. (elevation)

(d) Where possible paving join points shall be marked - Join (elev)

11. Miscellaneous points to remember.

(a) When placing new curb where sidewalk is existing, check to see
    that sidewalk is above the new curb grade allowing a minimum
    grade across the sidewalk area or parkway of 1% and a
    maximum of 6%, otherwise replace the sidewalk.

(b) Indicate profile numbers on all intersecting streets shown
    and direction and rate of grade.

(c) Indicate type of existing pavement at or near join points
    with new pavement.

(d) When replacing an existing pavement the new pavement shall be
    the same type and thickness as the existing pavement or as
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(e) It costs money to remove and reconstruct existing improvements
    so avoid removing so far as possible, but remove any existing
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    improvement.

(g) Don't change elevations or dimensions for 0.02' or less.
11. Misc. points to remember. Continued

(h) Checkers do not change anything on a plan without consulting the man who worked up the job. In event of a dispute get opinion of leader.

CHECK LIST

1. Plotting of existing improvements on profiles.
2. Plotting of existing improvements on cross-sections.
3. Proposed Grades on profiles.
   (a) Are vertical curves long enough - i.e. - is the difference between successive rates of grade less than 1.25% (b) Does new grade fit any existing sidewalk which is not being removed? (c) Does new grade fit improvements on abutting private property? (d) If grade is for pavement cover job, is there sufficient cover? (e) If there is considerable fall around any curb return, has a sidewalk grade been figured for the property line?
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5. Layout of plan (use scale and protractor).
   (a) Street widths. (b) Curb line distance from property line.
   (c) Location and type of existing improvements. (d) Proposed improvements. (e) Orientation of North Point.
7. Calculations for new alignments.
8. Transfer of alignment data from calculation sheets to plan.
9. Transfer of elevations and curb faces from work sheet to plan.
11. Join points for all new improvements.
12. Construction notes.
13. Removal notes.
14. Field Book and Profile References.
15. North Point.
16. Scale.
17. Title (a) Location and limits of work. (b) Job title and number.
18. Work stamp; designed by &c.
19. City Engineer’s approval stamp.
20. Acceptance Stamp.
SPECIAL ORDER

63570

TO ALL: Deputy Engineers
Division Engineers
District Engineers

Subject: Policy on Vertical Curves

August 14, 1961

Vertical curves shall be of sufficient length to provide adequate sight distance and comfortable vertical acceleration for the assumed design speed of the highway. Except for certain cases noted below, a minimum stopping sight distance at least equal to the safe stopping distance shall be provided on all curves.

I NOTATION

L = Length of vertical curve in feet.
A = Algebraic difference in grades in per cent/100.
S = Sight distance in feet.
V = Design speed in miles per hour.
D = Safe stopping distance in feet.
d = Distance between grade breaks in feet.
a = Vertical acceleration in feet/sec./sec.
R = L/A = Minimum radius of vertical curve in feet.

II SAFE STOPPING DISTANCE

The safe stopping distance shall conform to the recommendations of the American Association of State Highway Officials. Safe stopping distance equals the reaction distance (D1) + the braking distance (D2).

\[ D_1 = 1.47V (3.75-0.025V) \]
\[ D_2 = \frac{0.0334V^2}{0.575-0.0025V} \]
\[ D = 1.47(3.75-0.025V) + \frac{0.0334V^2}{0.575-0.0025V} \]

The attached chart gives safe stopping distances for speeds from 20 to 70 miles per hour.

III SIGHT DISTANCE REQUIREMENTS

1. Summit Curves.
   A. Stopping Sight Distance.
      Provide visibility for a 4 inch object at least equal to the safe stopping distance for the design speed of the highway. Height of eye is assumed to be 4.5 feet.
When $S$ is less than $L$, $S = 3.82 \sqrt{\frac{L}{A}}$

When $S$ is greater than $L$, $S = \frac{7.28}{A} + L$

<table>
<thead>
<tr>
<th>Class of Highway</th>
<th>Design Speed M.P.H.</th>
<th>Safe Stopping Distance = Stopping Sight Distance-feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>Secondary</td>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>Collector</td>
<td>40</td>
<td>275</td>
</tr>
<tr>
<td>Local-Flat</td>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>Local-Hillside</td>
<td>25</td>
<td>150</td>
</tr>
</tbody>
</table>

A chart showing length of vertical curve and stopping sight distance for values of $A$ from 0.01 to 0.12 is attached.

B. Summit Curves Adjacent To Intersections.
Summit vertical curves which hide an intersection should be of sufficient length to provide visibility for a vehicle to enter a main highway from the hidden intersection without being overrun by vehicles traveling at normal speed on the main highway. Heights of eye and vehicle are assumed to be 4.5 feet.

When $S$ is less than $L$, $S = 6.00 \sqrt{\frac{L}{A}}$

When $S$ is greater than $L$, $S = \frac{18}{A} + \frac{L}{2}$

<table>
<thead>
<tr>
<th>Class of Highway</th>
<th>Design Speed M.P.H.</th>
<th>Roadway Width Feet</th>
<th>Vehicle Sight Distance at Intersection - Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>50</td>
<td>80</td>
<td>650</td>
</tr>
<tr>
<td>Secondary</td>
<td>50</td>
<td>64</td>
<td>600</td>
</tr>
<tr>
<td>Collector</td>
<td>40</td>
<td>40</td>
<td>450</td>
</tr>
<tr>
<td>Local-Flat</td>
<td>30</td>
<td>36</td>
<td>350</td>
</tr>
<tr>
<td>Local-Hillside</td>
<td>25</td>
<td>28</td>
<td>300</td>
</tr>
</tbody>
</table>

2. Sag Curves.
A. Stopping Sight Distance.
Provide headlight visibility, except on lighted highways, at least equal to the safe stopping distance for the design speed of the highway. The headlight is assumed to be 2.5 feet above the pavement surface with a maximum deviation of the beam above the horizontal of one degree of arc.
When $S$ is less than $L$, $L = \frac{AS^2}{s + 0.035}$

When $S$ is greater than $L$, $L = \frac{2S - 5 + 0.035S}{A}$

<table>
<thead>
<tr>
<th>Class of Highway</th>
<th>Design Speed (M.P.H.)</th>
<th>Headlight Sight Distance = Safe Stopping Distance (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>Secondary</td>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>Collector</td>
<td>40</td>
<td>275</td>
</tr>
<tr>
<td>Local-Flat</td>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>Local-Hillside</td>
<td>25</td>
<td>150</td>
</tr>
</tbody>
</table>

The attached chart gives length of vertical curve and headlight sight distance for values of $A$ from 0.03 to 0.12.

IV COMFORTABLE RIDING REQUIREMENTS


Where it is unnecessary to provide stopping sight distance equal to the safe stopping distance, as for example on a lighted sag curve, vertical curves shall be of sufficient length to produce no perceptible sensation of vertical acceleration. The maximum vertical acceleration which will pass unnoticed on a vertical curve is approximately 2 feet/sec./sec. (See Highway Research Board Bulletin No. 149, 1957). Using a value of 1.79 feet/sec./sec. for maximum vertical acceleration, the minimum length of vertical curve will be

$$L = 1.2 AV^2$$

The length of curve given by this formula shall be used only when sight distance requirements do not govern.


There will be a few instances such as approaches to cross gutters and warped surfaces in intersections where, due to space limitations, it will be necessary to use vertical curves which produce a definite sensation of vertical acceleration. The maximum comfortable vertical acceleration is between 4 and 5 feet/sec./sec. Using a value of 4.30 feet/sec./sec. for "a", the minimum length of vertical curve for comfortable riding will be

$$L = 0.50 AV^2$$
This type of curve should be used only at approaches to cross gutters in intersections and on riding lines in intersections along the produced curb lines. A chart based on this formula showing the length of 3 reversing identical vertical curves crossing a dip or summit is attached.

V DEFINITION OF VERTICAL CURVES

1. Type of Curve.

The true parabola shall be used for all vertical curves in order to permit the sight distance and the speed to be calculated or scaled from charts. The sight distance and speed cannot be calculated for curves with unequal grade breaks or for curves with equal grade breaks including the two end breaks - neither of these curves are true parabolas - and time consuming graphical methods must be resorted to for a determination of the sight distance and the safe speed.

2. Profile Information

The length of all vertical curves on the center line of the roadway shall be shown on the profile. Tangent grades and B.C.'s and E.C.'s shall also be shown.

3. Distance Between Grade Breaks

Grade breaks on vertical curves shall be shown on the profile at such intervals that, assuming the curve to be constructed as a series of chords, the maximum difference between the chord and the true curve shall not be greater than 0.02 of a foot. The distance between grade breaks which will limit this difference to 0.02 of a foot is given by the following formula:

\[ d = 0.4 \frac{L}{A} \]

4. Definition of Vertical Curves By Minimum Radius.

All of the formulas used in the investigation and calculation of vertical curves contain the ratio \( L/A \). It can be shown that \( L/A \) is equal to the minimum radius of a parabola. The minimum radius of a parabola occurs at the point where the slope of the tangent to the curve is zero. On a summit curve connecting a plus and minus grade it is located at the highest point on the curve. On a sag curve with the same conditions it will be located at the lowest point on the curve. On curves connecting two plus or two minus grades it would not occur on the finite curve but on the imaginary prolongation of the curve at the point.
where the tangent grade is zero. Since both the sight distance and the riding qualities of a vertical curve are functions of the minimum radius it is possible to specify minimum radii for vertical curves which will provide any desired sight distance or comfortable speed. The following table gives minimum radii for vertical curves which will meet the sight distance and speed requirements described in this policy.

<table>
<thead>
<tr>
<th>Class of Highway</th>
<th>Design Speed M.P.H.</th>
<th>L/A=R= MINIMUM RADIUS OF PARABOLA-FEET</th>
<th>SIGHT DISTANCE</th>
<th>SPEED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>SUMMIT CURVES</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4&quot;)Object R=S2/14.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4.5”Vehcl *R=S2/36</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SAG CURVES Headl't R=S2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5+0.035S</td>
<td></td>
</tr>
<tr>
<td>PRIMARY</td>
<td>50</td>
<td>8413</td>
<td>11,736</td>
<td>7101</td>
</tr>
<tr>
<td>SECONDARY</td>
<td>50</td>
<td>8413</td>
<td>10,000</td>
<td>7101</td>
</tr>
<tr>
<td>COLLECTOR</td>
<td>40</td>
<td>5194</td>
<td>5,625</td>
<td>5171</td>
</tr>
<tr>
<td>LOCAL-</td>
<td>30</td>
<td>2747</td>
<td>3,403</td>
<td>3333</td>
</tr>
<tr>
<td>FLAT</td>
<td>25</td>
<td>1545</td>
<td>2,500</td>
<td>2195</td>
</tr>
<tr>
<td>LOCAL-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HILLSIDE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRIMARY</td>
<td>50</td>
<td></td>
<td>1250</td>
<td></td>
</tr>
<tr>
<td>SECONDARY</td>
<td>50</td>
<td></td>
<td>1250</td>
<td></td>
</tr>
<tr>
<td>COLLECTOR</td>
<td>40</td>
<td></td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>LOCAL-</td>
<td>30</td>
<td></td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>FLAT</td>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HILLSIDE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Use this column when curve is adjacent to an intersection.

The use of this table is illustrated by the following examples:

1. Given a summit curve connecting a + 6% grade and a - 2% grade. Design speed is 50 miles per hour. Calculate minimum length of curve for stopping sight distance.
   \[ A = \frac{+6-(-2)}{100} = 0.08 \]

   From the table opposite design speed of 50 m.p.h. and under column headed "Summit Curve-4" Object," read \( R=8413 \) feet.
   Then \( L=8413 \times 0.08 = 673.04 \) feet which is the minimum length of curve to provide stopping sight distance for 50 m.p.h.

2. Given a sag curve connecting a + 5% grade and a - 4% grade. Design speed is 50 m.p.h. Calculate minimum length of curve for a lighted highway.
   \[ A = \frac{+5-(-4)}{100} = 0.09 \]
From the table opposite 50 m.p.h. design speed and under column headed "Speed - No Apparent Acceleration," read $R = 3000$ feet. Then $L = 3000 \times 0.09 = 270$ feet which is the minimum length of a sag curve for 50 m.p.h. on a lighted highway.

3. Given a summit curve. 50 miles per hour design speed. Length = 600 feet. Algebraic difference in grades = 7%. Is stopping sight distance of a 4 inch object satisfactory for the design speed?

$$R = \frac{L}{A} = \frac{600}{7/100}$$

From table opposite 50 m.p.h. design speed and under column headed "Summit Curves - 4" Object," read $R = 8413$ feet which is less than radius furnished. Curve is satisfactory.

Lyall A. Pardee
City Engineer

DT: jm
August 15, 1961
Reprint April, 1964
SAFE STOPPING DISTANCES

A.A.S.H.O. FORMULA

\[ S = D' + D \]

\[ D' = 1.47V(3.75 - 0.025V) \]

\[ D = \frac{0.0334V^2}{0.575 - 0.0025V + G} \]

\[ V = \text{VELOCITY - M.P.H.} \]

\[ G = \text{GRADE - \%} \]

A.A.S.H.O. STANDARDS

<table>
<thead>
<tr>
<th>DESIGN SPEED</th>
<th>STOPPING DISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>M. P. H.</td>
<td>FEET</td>
</tr>
<tr>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>40</td>
<td>275</td>
</tr>
<tr>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>60</td>
<td>475</td>
</tr>
<tr>
<td>70</td>
<td>600</td>
</tr>
</tbody>
</table>

D. THOMPSON 10-43
STopping sight distance on vertical curves

A.A.S.H.O. Standards

Height of eye 4.5 feet
Height of object 4 inches

L = Length of vertical curve in stations
A = Algebraic difference of grades in %
S = Sight distance in feet
V = Safe speed in M.P.H. for S

When S > L
\[ S = \frac{728 + 50L}{A} \]

When S < L
\[ S = 382 \sqrt{\frac{L}{A}} \]

<table>
<thead>
<tr>
<th>Design Speed (M.P.H.)</th>
<th>Sight Distance (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>40</td>
<td>275</td>
</tr>
<tr>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>60</td>
<td>475</td>
</tr>
<tr>
<td>70</td>
<td>600</td>
</tr>
</tbody>
</table>

D. Thompson 4-43
A = ALGEBRAIC DIFFERENCE IN GRADES - FEET
L = LENGTH OF VERTICAL CURVE - FEET
S = SIGHT DISTANCE - FEET

WHEN S < L
\[ L = \frac{A^2 S}{5 + 0.035 S} \]

WHEN S > L
\[ L = 2S - \frac{5 + 0.035 S}{A} \]

### A.A.S.H.O. STANDARDS

<table>
<thead>
<tr>
<th>DESIGN SPEED M.P.H.</th>
<th>SIGHT DISTANCE FEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>200</td>
</tr>
<tr>
<td>40</td>
<td>275</td>
</tr>
<tr>
<td>50</td>
<td>350</td>
</tr>
<tr>
<td>60</td>
<td>475</td>
</tr>
<tr>
<td>70</td>
<td>600</td>
</tr>
</tbody>
</table>
COMFORTABLE SPEED ON VERTICAL CURVES
THREE REVERSING VERTICAL CURVES CROSSING A DIP OR SUMMIT
ALL CURVES WITH EQUAL RATES OF GRADE CHANGE

L = 2.83V(1/D) G = 0.5A + G G2 = 0.5A - G
L = LENGTH FT, VELOCITY M.P.H. = V
A = ALGEBRAIC DIFFERENCE IN GRADES-%
D = MAXIMUM OFFSET - FT.
G = RULING GRADE-%
A (%) = 8D(X100)

EXAMPLE
GIVEN D = 2 FT. V = 50 M.P.H. G = 1 %.
ON HORIZONTAL LINE D = 2 FT. FIND INTER-
SECTION WITH V = 50 AND READ L = 200
AND A = 8. THEN G = 5 % AND G2 = 3 % AND
CURVES CAN BE PLATTED.

FORMULA FOR L WAS DERIVED FROM FORMULA L1 = 0.005AV^2
WHERE L1 IS LENGTH OF ONE CURVE.

D = MAXIMUM OFFSET IN FEET
L = LENGTH IN FEET.
MINIMUM RADII FOR STOPPING SIGHT DISTANCE ON VERTICAL CURVES

S = STOPPING SIGHT DISTANCE IN FEET
R = MINIMUM RADIUS OF VERTICAL CURVE IN FEET

SAG CURVES
\[ S = \frac{5}{3} R \]

SUMMIT CURVES
\[ S = \frac{L}{A} = \frac{5}{14.56} \]

L = LENGTH OF CURVE - FT.
A = ALGEBRAIC ANGLE - % / 100

D. THOMPSON 8-46
TO ALL: DEPUTY ENGINEERS
DIVISION ENGINEERS
DISTRICT ENGINEERS

Subject: Policy on
Superelevation of
Horizontal Curves

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 0.30 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.
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 RADII Reversing Curves E = 0.06 ft./ft.</th>
<th>MINIMUM RADII 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>Collect</td>
<td>30</td>
<td>212</td>
<td>120</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>314</td>
<td>135</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>443</td>
<td>150</td>
</tr>
<tr>
<td>45</td>
<td></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>55</td>
<td></td>
<td>994</td>
<td>219</td>
</tr>
<tr>
<td>60</td>
<td></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

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

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

FACTOR OF SAFETY FOR F AT MAXIMUM SAFE SPEED
AGAINST SIDE SKIDDING = \( \frac{F_{AT\ IMPELLING\ SIDE\ SKID}}{F_{FOR\ MAXIMUM\ SAFE\ SPEED}} \)

F.S. AT 100 M.P.H. = 0.30
F.S. AT 20 M.P.H. = 0.50

SIDE SKID IMPENDING

○ - NOBLE & STONEX. HIGHWAY RESEARCH BOARD 1940
□ - MOYER & BERRY. ASPHALT HIGHWAY RESEARCH BOARD 1940
△ - MOYER & BERRY. CONCRETE HIGHWAY RESEARCH BOARD 1940

MAXIMUM SAFE SPEED

○ - STOHNER. HIGHWAY RESEARCH BOARD BULLETIN
♦ - DONALD THOMPSON. UNPUBLISHED PAPER. CITY OF LOS ANGELES

D. Thompson Feb. 1961
maximum safe speed on horizontal curves

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

\[ E = \text{superelevation - Ft./Ft.} \]
\[ F = \text{side friction - Ft./Ft.} \]

\[ V = \text{velocity - miles per hour} \]
\[ R = \text{radius - Ft.} \]

\[ V = \text{velocity - miles per hour} \]

\[ F' \text{ for maximum safe speed} \]

\[ F' \text{ at impending side skid} \]

\[ E = \text{superelevation - Ft./Ft.} \]

\[ V = \text{maximum safe speed - miles per hour} \]

D. Thompson Feb. 1961
CITY OF LOS ANGELES  
LYALL A. PARDEE  
CITY ENGINEER

SUPERELEVATION FOR CITY STREETS AND HIGHWAYS

MAXIMUM SUPERELEVATION = 0.06 FT. PER FT.

R = RADIUS - FT.

SUPERELEVATION TRANSITION

MAX. L = \frac{472(F_v)(V)}{C}

F = MAX. SAFE SIDE FRICTION - FT./FT.
C = RATE OF CHANGE OF F. FT./SEC.

SEE TABLE 1

FOR RADIUS LARGER THAN MINIMUM, \( L = (MAX. L)(MIN. R) \)

L SHOULD BE A MULTIPLE OF 3

TRANSITION PROFILE

CROWN RUNDOUT  TRANSITION LENGTH  FULL SUPER

OUTSIDE EDGE

CROSS SECTIONS
PAVEMENT REVOLVED ABOUT \( \theta \)

SUPERELEVATION

MIN. R = \frac{V^2 [1 - (MAX. E)(F_v)]}{15 (MAX. E + F_v)}

MAX. E = 0.06 FT./FT.
FOR RADIUS LARGER THAN MINIMUM, E = \( \frac{(MIN. R)(MAX. E)}{R} \)

F_v = MAXIMUM SAFE F FOR DESIGN SPEED. SEE TABLE 1.

D. Thompson  Feb. 1961
# TABLE 1

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

**FORMULAS**

1. **SUPERELEVATION**

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

2. **LENGTH OF SUPERELEVATION TRANSITION**

\[
L = \frac{47.2VF}{C}
\]

- **E**: SUPERELEVATION SLOPE - FT./FT.
- **F**: SIDE FRICTION FACTOR OR UNBALANCED THRUST - FT./FT.
- **V**: VELOCITY - MILES PER HOUR
- **R**: RADIUS - FT.
- **L**: LENGTH OF SUPERELEVATION TRANSITION - FT.
- **C**: RATE OF INCREASE OF F IN FT./SEC.³

<table>
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<tr>
<th>DESIGN SPEED M.P.H.</th>
<th>MAXIMUM E</th>
<th>MAXIMUM F</th>
<th>E + F</th>
<th>I - EF</th>
<th>MINIMUM RADIUS FEET</th>
<th>C/SEC³</th>
<th>MAXIMUM TRANSITION FEET</th>
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**SUPERELEVATION ON CURVES WITH RADIUS 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 RADIUS 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 \( \frac{k}{3} \) 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 Super-elevation - 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

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

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

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. \& Radius is:
\[ F.S. = \frac{31.5 \text{ MPH}}{25.0 \text{ MPH}} = 1.26 \]

D. Thompson 1961
Access Ramp Detail

No Scale

NOTE:
Const. per std.
Plan S-440-1

Conc. Walker,
4'' SNL.

1/8 C.F. 31
1/8 C.F. 4'

Type B Curb on 8'' PMD

Curb
ECR

403

8+00

7+63 Match Line
See Sh+3

Private

DESIGNED BY
DRAWN BY
CHECKED BY
PROJECT ENG.

S.L.E. 81
S.L.E. 81
M.D.

30' 15'

100' 35' 35' 15'

8

10
A PAVEMENT RATING SYSTEM
FOR LOW-VOLUME ASPHALT ROADS

INTRODUCTION

For those individuals or agencies with the responsibility of maintaining low-volume roads and streets, deciding which roads should get first attention is often difficult. One factor complicating the decision is the variety of types of pavement distress — some serious, others rather insignificant. This publication presents a system that utilizes the experience of an engineer, maintenance superintendent, or foreman to assign a numerical value to each type of pavement defect, taking into account both the extent of distress and its relative seriousness. The sum of these numerical values provides a fairly accurate, though subjective, index of the general condition of the road. The index can be useful in setting maintenance priorities.

Part 1 of this publication explains the pavement condition rating system. Part 2 contains photographs and descriptions of the different types of distress.

PART 1

WHERE THE SYSTEM APPLIES

The rating system is intended for agencies or organizations not having the benefit of specialized highway engineering experience and without access to conventional testing facilities. It is designed to apply to relatively low-volume roads and streets — those that carry fewer than 1,000 cars and 50 trucks per day.

MAKING THE INSPECTION

An effective way of inspecting a pavement is first to drive slowly over the road to get an overall impression of its condition. Then, to make a thorough inspection on foot, making rough notes on the type and extent of distress as one goes along. When the inspection is completed, the rating form is filled out. It may be useful to drive again slowly over the pavement after filling out the rating form. Since the system is based on personal judgment, better results are obtained when two or more experienced individuals independently rate the pavements and the results are averaged.

RATING A ROAD

As mentioned earlier, some defects affect the performance of a pavement more than others. Under this rating system, the less serious problems are assigned values between 0 and 5. Defects of a more serious nature — those directly related to the strength of the pavement — are rated on a scale of 0 to 10. A rating of 0 means that the pavement is free of that particular type of distress. Part 2 of this publication should be helpful in identifying the different types of defects.

When assigning a rating to a particular type of defect, it is important to consider both its extent and severity. For example, a rating of 10 for “rutting” would indicate that it occurs on much or all of the road, and that the ruts are probably deep enough to be a safety hazard, especially during rain, and an impediment to traffic at all times. On the other hand, a rating of 1 for “corrugations” would indicate that corrugations, although evident, are not numerous and that at present the distortions are not very large.

After each defect is rated, the individual ratings are added. This sum is then subtracted from 100, and the result is simply called the “condition rating.”
## ASPHALT PAVEMENT RATING FORM

**STREET OR ROUTE**

**CITY OR COUNTY**

**LENGTH OF PROJECT**

**WIDTH**

**PAVEMENT TYPE**

**DATE**

(Note: A rating of “0” indicates defect does not occur)

<table>
<thead>
<tr>
<th>DEFECTS</th>
<th>RATING</th>
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<tbody>
<tr>
<td>Transverse Cracks</td>
<td>0-5</td>
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<tr>
<td>Longitudinal Cracks</td>
<td>0-5</td>
</tr>
<tr>
<td>Alligator Cracks</td>
<td>0-10</td>
</tr>
<tr>
<td>Shrinkage Cracks</td>
<td>0-5</td>
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<tr>
<td>Rutting</td>
<td>0-10</td>
</tr>
<tr>
<td>Corrugations</td>
<td>0-5</td>
</tr>
<tr>
<td>Raveling</td>
<td>0-5</td>
</tr>
<tr>
<td>Shoving or Pushing</td>
<td>0-10</td>
</tr>
<tr>
<td>Pot Holes</td>
<td>0-10</td>
</tr>
<tr>
<td>Excess Asphalt</td>
<td>0-10</td>
</tr>
<tr>
<td>Polished Aggregate</td>
<td>0-5</td>
</tr>
<tr>
<td>Deficient Drainage</td>
<td>0-10</td>
</tr>
</tbody>
</table>

**Overall Riding Quality (0 is excellent; 10 is very poor):**

| 0-10                     |

**Condition Rating**

\[
\text{Condition Rating} = 100 - \text{Sum of Defects}
\]

\[
= 100 - 
\]

**Condition Rating** = [space]
INTERPRETING THE CONDITION RATING

There are two ways that the condition rating can be used. First, as a relative measurement, it provides a rational method for ranking roads and streets according to their condition.

Secondly, as an absolute measure, the condition rating provides a general indicator of the type and degree of repair work necessary. As a very general rule, if the condition rating is between 80 and 100, normal maintenance operations such as crack-filling, pot hole repair, or perhaps a seal coat are usually all that is required. If the condition rating falls below 80, it is likely that an overlay will be necessary. In this event, it may be advisable to contact the nearest Asphalt Institute or other similarly qualified engineer for assistance. If the condition rating is below 30, chances are that major reconstruction is necessary; this is illustrated in Figure 2.

<table>
<thead>
<tr>
<th>RECONSTRUCTION</th>
<th>PATCHING AND OVERLAY</th>
<th>ROUTINE MAINTENANCE</th>
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<td>40</td>
</tr>
<tr>
<td>80</td>
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<td></td>
</tr>
</tbody>
</table>

CONDITION RATING AS A GENERAL INDICATOR OF TYPE OF MAINTENANCE

Figure 2.

PART 2

PAVEMENT DEFECTS

CAUSES OF PAVEMENT DEFECTS

Although a detailed discussion of the subject is beyond the scope of this publication, an understanding of the cause of a pavement defect is essential before an attempt is made to remedy it. Similarly, efficient use of a maintenance budget requires that proven methods be used to prevent recurrence of a problem. Accompanying the illustrations of defects that follow, there is a brief statement of their usual cause and the suggested means of repair. If more detailed assistance is needed in determining either the cause of a defect or the proper method of its repair, it may be advisable to contact the nearest Asphalt Institute office listed on the back cover. Other Asphalt Institute publications that might be particularly useful are: *Full-Depth Asphalt Patching*, CL-19; *Asphalt in Pavement Maintenance*, MS-16; *Asphalt*
TRANSVERSE CRACK — A crack that follows a course approximately at right angles to the pavement centerline.

This frequently is caused by movement in the pavement beneath the asphalt layer (reflection cracking). Can also result from stresses induced by low-temperature contraction of the pavement.

Requires filling with asphalt emulsion slurry. This is usually (but not necessarily) followed by a seal coat or overlay over the entire surface.

LONGITUDINAL CRACK — A crack that follows a course approximately parallel to the centerline.

This usually results from a weak joint between paving lanes. These cracks can also result from earth movements, particularly on embankments. Two closely-spaced longitudinal cracks in a wheel path usually indicate bending stress induced by rutting. Longitudinal cracks can also occur as a result of movement in the pavement beneath the asphalt layer (reflection cracking).

For repair, see “Transverse Crack.”

ALLIGATOR CRACKS — Interconnected cracks forming a series of small polygons, the pattern resembling an alligator’s skin.

Caused by excessive deflection of the surface over unstable subgrade or lower courses of the pavement. The unstable support usually is the result of saturated granular bases or subgrade.

Requires deep patching.
SHRINKAGE CRACKS — Interconnected cracks forming a series of large polygons, usually having sharp angles at the corners.
Caused by volume change in the asphalt mix or in the base or subgrade.
Requires crack filling with asphalt emulsion slurry followed by a surface treatment or a slurry seal over the entire surface.

RUTTING — Longitudinal depressions that form under traffic in the wheel paths and have a minimum length of approximately 6 m (20 ft).
Caused by consolidation or lateral movement under traffic in one or more of the underlying courses, or by displacement in the asphalt surface layer itself.
Ruts should be filled with hot plant-mixed material to restore proper cross section. This should be followed by a thin overlay.

CORRUGATIONS — Transverse undulations at regular intervals in the surface of the pavement consisting of alternate closely-spaced valleys and crests.
Caused by lack of stability in asphalt layers. Requires repair before resurfacing. If the corrugated pavement has an aggregate base with a thin surface treatment, a satisfactory corrective measure is to scarify the surface, mix it with the base, and recompact the mixture before resurfacing. If the pavement has more than 5 cm (2 in.) of asphalt surfacing and base, shallow corrugations can be removed with a pavement planing machine, better known as a "heater-planer." This is followed with a seal coat or overlay.

RAVELING — The progressive disintegration from the surface downward, or edges inward by the dislodgement of aggregate particles.
Caused by lack of compaction during construction, construction during wet or cold weather, dirty or disintegrating aggregate, too little asphalt in the mix, or overheating of the asphalt mix.
Usually requires a seal coat.
SHOVING — Lateral displacement of paving material due to the action of traffic, generally resulting in the bulging of the surface. Caused by lack of stability in asphalt layers. Requires removal of affected area, followed by deep patching.

POT HOLES — Bowl-shaped holes of varying sizes in the pavement, often the result of progressive deterioration of other defects such as alligator cracking. Usually caused by a combination of weaknesses in the pavement resulting from such as too little asphalt, too thin an asphalt surface, too many fines, too few fines, or poor drainage, and traffic. Requires deep patching.

POLISHED AGGREGATE — Aggregates in the surface of a pavement that have been polished smooth. Caused by naturally smooth uncrushed gravels and crushed rock that wears down quickly under action of traffic. Requires covering the surface with a skid resistant treatment.

EXCESS ASPHALT (BLEEDING) — Free asphalt on the surface of the pavement. Caused by too much asphalt in one or more of the pavement courses. In many cases, bleeding can be corrected by repeated applications of hot sand, hot slag screenings or hot rock screenings to blot up the excess asphalt. Sometimes, when bleeding is light, a plant-mixed surface treatment or an aggregate seal coat, using absorptive aggregate, is the only treatment needed. In rare instances of heavily over-asphalted surfaces, the surfaces should be completely removed.

DEFICIENT DRAINAGE — Drainage problems may be considered in two categories: surface and subsurface. Proper surface drainage efficiently removes runoff from the pavement and the nearby ground. Standing water on the pavement or in the side ditches indicates surface drainage deficiency. Proper subsurface drainage keeps groundwater away from the pavement structure. Two indicators of deficient subsurface drainage are, in the absence of precipitation, water in a side ditch, or alligator cracking with moisture in the cracks.

For information on alleviation of drainage problems, the reader is referred to Drainage of Asphalt Pavement Structures, MS-15, The Asphalt Institute.