# TABLE OF CONTENTS

## CROSS-SECTION ELEMENTS (E 400)

<table>
<thead>
<tr>
<th>SECTION NO.</th>
<th>SUBJECT</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>E 410</td>
<td>STREETS</td>
<td>Sept., 1970</td>
</tr>
<tr>
<td>E 411</td>
<td>Standard Nomenclature of Street Cross-Section Elements</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 411.1</td>
<td>Structural Elements</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 411.11</td>
<td>Geometric Elements</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 412</td>
<td>Width Standards and Component Arrangements</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 412.1</td>
<td>Street Cross-Sections</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 412.11</td>
<td>Alleys</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 412.12</td>
<td>Pedestrian Walks (Inner Block Walks)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 412.2</td>
<td>Pavement Traffic lanes</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 412.21</td>
<td>Lane Widths</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 412.22</td>
<td>Lane Arrangements</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 420</td>
<td>PAVEMENTS</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 421</td>
<td>Geometric Cross-Section</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 421.1</td>
<td>Parabolic Crown Sections</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 421.2</td>
<td>Special Sections</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422</td>
<td>Pavement Design (Structural)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.1</td>
<td>Flexible Pavements</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.11</td>
<td>Flexible Pavement Design</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.111</td>
<td>Traffic Evaluation</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.112</td>
<td>Soil Evaluation</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.113</td>
<td>Required Soil Information</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.114</td>
<td>Slab Strength</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.115</td>
<td>Structural Section Design Examples</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.116</td>
<td>Recommended Standard Practice</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.2</td>
<td>Rigid Pavement Design</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.21</td>
<td>Where Concrete Pavement Is Used</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.22</td>
<td>Concrete Pavement Thickness</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 422.23</td>
<td>Concrete Pavement Removal</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 423</td>
<td>CURBS</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431</td>
<td>Structural Types and Uses</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431.1</td>
<td>Permanent Curbs</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431.11</td>
<td>Barrier Curbs</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431.111</td>
<td>Type &quot;A&quot; light Curb</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431.112</td>
<td>Type &quot;B&quot; Heavy Curb</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431.113</td>
<td>Type &quot;C&quot; Integral Concrete Curb and Concrete Gutter</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431.114</td>
<td>Extruded or Doweled Curbs</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431.12</td>
<td>Mountable Curbs</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 431.2</td>
<td>Temporary Curbs (Berms)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 432</td>
<td>Curb Placement</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 433</td>
<td>Miscellaneous Curb Design Details</td>
<td>&quot;</td>
</tr>
<tr>
<td>SECTION NO.</td>
<td>SUBJECT</td>
<td>DATE</td>
</tr>
<tr>
<td>-------------</td>
<td>---------</td>
<td>------</td>
</tr>
<tr>
<td>E 433.1</td>
<td>Curb Transitions</td>
<td>Sept., 1970</td>
</tr>
<tr>
<td>E 433.2</td>
<td>Curb Measuremements of Horizontal Offsets</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 433.3</td>
<td>Curb Return Radii</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 433.4</td>
<td>Curb Face Heights</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 433.5</td>
<td>Curb Removal</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 440</td>
<td>CONCRETE GUTTERS</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441</td>
<td>Type of Gutter</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.1</td>
<td>Longitudinal Gutter (Adjacent to the Curb)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.11</td>
<td>Transverse and Longitudinal Gutter Slopes</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.111</td>
<td>Transverse Slopes</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.112</td>
<td>Longitudinal Slopes</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.113</td>
<td>Hydraulic Capacity of Gutter</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.114</td>
<td>Warping Gutter at Drainage Structures</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.2</td>
<td>Longitudinal Gutter (Not Adjacent to the Curb)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.3</td>
<td>Cross-Gutters</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.31</td>
<td>Standard Cross-Gutter</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.32</td>
<td>Low Flow Channel Cross-Gutter</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 441.33</td>
<td>Cross-Gutters Located at Other Than Intersections</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 450</td>
<td>BORDERS</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 451</td>
<td>Block Corner Property Lines</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 452</td>
<td>Sidewalks</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 452.1</td>
<td>Locations</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 452.2</td>
<td>Widths</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 452.3</td>
<td>Types of Materials, Thickness, and Construction Practices</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 452.4</td>
<td>Sidewalk Design</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 452.5</td>
<td>Sidewalk Design at Intersections</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 453</td>
<td>Parkways</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 454</td>
<td>Shoulders</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 460</td>
<td>MEDIANS</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 461</td>
<td>Use of Medians (General)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 462</td>
<td>Types of Medians</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 462.1</td>
<td>Painted Medians or Pavement Markers</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 462.11</td>
<td>Advantages</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 462.12</td>
<td>Disadvantages</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 462.2</td>
<td>Curbed Medians</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 462.21</td>
<td>Advantages</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 462.22</td>
<td>Disadvantages</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 462.3</td>
<td>Mountable Curbed Medians</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 463</td>
<td>Width Standards Determination of Medians</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464</td>
<td>Median Left-Turn Lanes (Pockets)</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.1</td>
<td>General</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.11</td>
<td>design Factors</td>
<td>&quot;</td>
</tr>
<tr>
<td>SECTION NO.</td>
<td>SUBJECT</td>
<td>DATE</td>
</tr>
<tr>
<td>------------</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>E 464.12</td>
<td>Storage Length</td>
<td>Sept., 1970</td>
</tr>
<tr>
<td>E 464.13</td>
<td>Deceleration</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.14</td>
<td>Through-Traffic Queue</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.15</td>
<td>Physical Geometric Limitations</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.16</td>
<td>Vehicle Characteristics</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.17</td>
<td>Topography</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.18</td>
<td>Required Parking Restrictions</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.19</td>
<td>Projected Land Use</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.2</td>
<td>Left-Turn Lane Layout</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.21</td>
<td>Transition</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.22</td>
<td>Approach Tangent</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.23</td>
<td>Taper</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.24</td>
<td>Length</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.25</td>
<td>Width</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 464.3</td>
<td>Nanintersection Left Turns</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 465</td>
<td>Grade Determination of Medians</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 466</td>
<td>Drainage Considerations</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 467</td>
<td>Cross-Section of Curbed Median</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 467.1</td>
<td>Transverse Grade</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 467.2</td>
<td>Structural Cross-Section</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 467.3</td>
<td>Landscaping</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 470</td>
<td>RETAINING WALLS AND BULKHEADS</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 471</td>
<td>General</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 480</td>
<td>SIDE SLOPES</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 481</td>
<td>Side Slope Design Requirements</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 482</td>
<td>Benches and Terraces</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 483</td>
<td>Economic Considerations</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 484</td>
<td>Esthetic Considerations</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 490</td>
<td>TRAFFIC GUIDES AND BARRIER INSTALLATIONS</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 491</td>
<td>Choice Location and Type</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 491.1</td>
<td>Uses</td>
<td>&quot;</td>
</tr>
<tr>
<td>E 491.2</td>
<td>Placement</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>TITLE</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>E 411</td>
<td>Structural Elements of Typical Sections</td>
<td>Sept., 1970</td>
</tr>
<tr>
<td>E 421.1A(1)</td>
<td>Examples of Detailing Pavement Cross-Sections (Sheet 1)</td>
<td></td>
</tr>
<tr>
<td>E 421.1A(2)</td>
<td>Examples of Detailing Pavement Cross-Sections (Sheet 2)</td>
<td></td>
</tr>
<tr>
<td>E 421.1B</td>
<td>Defining Crown Section</td>
<td></td>
</tr>
<tr>
<td>*E 421.2</td>
<td>Special Section for Industrial Streets</td>
<td></td>
</tr>
<tr>
<td>*E 422.111</td>
<td>Traffic Indexes</td>
<td></td>
</tr>
<tr>
<td>*E 422.114</td>
<td>Gravel Equivalent Factor</td>
<td></td>
</tr>
<tr>
<td>E 422.115A</td>
<td>20-Year Conversion Chart (Average Daily Traffic to Traffic Index)</td>
<td></td>
</tr>
<tr>
<td>E 422.115B</td>
<td>Structural Design Chart for Flexible Pavements</td>
<td></td>
</tr>
<tr>
<td>E 431A</td>
<td>Special Curbs and Berms</td>
<td></td>
</tr>
<tr>
<td>E 431B</td>
<td>Special Curbs</td>
<td></td>
</tr>
<tr>
<td>E 431.1</td>
<td>Types of Curb and Gutter</td>
<td></td>
</tr>
<tr>
<td>*E 441.113</td>
<td>Longitudinal Slopes</td>
<td></td>
</tr>
<tr>
<td>E 441.114</td>
<td>Street Reconstruction Design Criteria at Catch Basins</td>
<td></td>
</tr>
<tr>
<td>E 441.33A</td>
<td>Street Plan</td>
<td></td>
</tr>
<tr>
<td>E 441.33B</td>
<td>Work Sheet Profile and Cross-Sections</td>
<td></td>
</tr>
<tr>
<td>E 451A</td>
<td>Block Corner Property Line Cut-Off</td>
<td></td>
</tr>
<tr>
<td>E 451B</td>
<td>Sidewalk Alignments at Intersections</td>
<td></td>
</tr>
<tr>
<td>E 452</td>
<td>Nomenclature for Pedestrian Rights of Way</td>
<td></td>
</tr>
<tr>
<td>E 464.2A</td>
<td>Striping Standards for Major Highways</td>
<td></td>
</tr>
<tr>
<td>E 464.2B</td>
<td>Striping Standards for Secondary Highways</td>
<td></td>
</tr>
<tr>
<td>E 464.2C</td>
<td>Diamond Interchange for Major and Secondary Highways</td>
<td></td>
</tr>
<tr>
<td>E 465</td>
<td>Cross-Sections Showing Crossfall and Superelevation</td>
<td></td>
</tr>
<tr>
<td>E 466</td>
<td>Street Cross-Sections With Curbed Medians</td>
<td></td>
</tr>
<tr>
<td>E 481A</td>
<td>Typical Cut and Fill Slopes</td>
<td></td>
</tr>
<tr>
<td>*E 481B</td>
<td>Grading in Back of Sidewalks</td>
<td></td>
</tr>
<tr>
<td>E 490(1)</td>
<td>Typical Installations of Traffic Guides and Warning Devices (Sheet 1)</td>
<td></td>
</tr>
<tr>
<td>E 490(2)</td>
<td>Typical Installations of Traffic Guides and Warning Devices (Sheet 2)</td>
<td></td>
</tr>
<tr>
<td>E 490(3)</td>
<td>Typical Installations of Traffic Guides and Warning Devices (Sheet 3)</td>
<td></td>
</tr>
</tbody>
</table>

*Figures preceded by asterisks are in text. All others are at ends of chapters.


E 400 CROSS-SECTION ELEMENTS

The various elements that go to make up a street, as well as the nomenclature of these elements, are discussed in the Sections and Sub-sections that follow.

E 410 STREETS

E 411 STANDARD NOMENCLATURE OF STREET CROSS-SECTION ELEMENTS

There is a tendency to interchange the terms of certain component parts of pavement and pavement support, as well as other features of street cross-section elements. The lack of a uniform terminology has resulted in confusion and misunderstanding of legal documents and of oral and written communications.

The following discussion includes the terminology used to describe structural and geometric elements. Reference is also made to the typical cross-sections shown on Figure E 411.

E 411.1 Structural Elements: The layers of materials which comprise the structural elements of a street are referred to as courses. These courses are put into place and brought to a specific grade. The top course is referred to as the surface course and the courses supporting the top course are called base courses. Since there are several types of base courses, the use of the term “base course” must also be qualified. For example, the term pavement base (course) is used for the layer below the surface course where two courses of pavement are used, the term subbase (course) where select material is required to support the pavement course(s), and the term stabilized subbase (course) where stabilization of the foundation or subsoil is used below the subbase course.

The term grade or subgrade, when used as a noun, indicates a line, surface, elevation, or place to which these courses are brought during construction. Where more than one course is used, each course is brought to a particular surface or plane and designated by the corresponding term, as illustrated on Figure E 411.

E 411.11 Geometric Elements: Two geometric terms requiring clarification of usage are roadbed and parkway. Refer to Figure E 411. The term “roadbed” applies to the width of street between the backs of curbs. It is not to be confused with foundation or subsoil, which is the undisturbed supporting soil within the roadbed limits. The term parkway is often used to describe the area between the back of curb and the front of walk, as well as the area between the face of the curb and the property line. AASHO suggests the use of the term border for that area located between the curb face and the property line. The term “parkway” would then be reserved to define the area between the back of curb and the front of walk.

E 412 WIDTH STANDARDS AND COMPONENT ARRANGEMENTS

The following Los Angeles Municipal Code ordinances either designate the Master Plan to be used or specify the street widths and/or arrangement of the street cross-section components.

1. Ordinance No. 122,064 (Division of Land) is used in new or proposed subdivisions of land.

2. Article 8 (Private Street Regulations) amended to, and including, Ordinance No. 122,064 contains the requirements to be met in the design of “Private Streets.”

3. Ordinance No. 120,796 (R-3 Ordinance) and Ordinance No. 125,340, an amendment to Section 12.37 of Ordinance No. 120,796, contain the requirements to be met for street widths in the development of land zoned R-3 or of any less restricted zone.

4. Ordinance No. 122,312 (Lot Split Ordinance) is used when subdividing parcels of land not under the jurisdiction of the State and City’s subdivision laws.

E 412.1 Street Cross-Sections: Figure E 113, Standard Street Dimensions, shows the standard street widths and cross-section component arrangement. The widths for alleys, private streets, and walks are discussed below. The sections illustrated are the standards for new streets. The sections designated for existing streets are the
desirable minimum standards and should be increased where practicable.

E 412.11 Alleys: Alleys servicing predominantly industrially zoned areas should be provided with a 30-foot width. Commercial and residential alleys require a 20-foot width.

E 412.12 Pedestrian Walks (Inner Block Walks): All new public walks or areas set aside for dedication as pedestrian walks should be provided with a 10-foot width. The design covering sidewalk grades discussed in Section E 452 should apply also to the design of pedestrian walks.

E 412.2 Pavement Traffic Lanes: These vary in width and arrangement, depending on the vehicular composition, speed, traffic movements, and available roadway width.

E 412.21 Lane Widths: The current design criteria used by the City of Los Angeles for traffic lane widths are as follows:

1. The absolute minimum width parking lane is 8 feet.
2. The desirable minimum width parking lane is 10 feet.
3. The absolute minimum width traffic lane is 9 feet.
4. The desirable minimum width traffic lane is 10 feet.
5. The standard width traffic lane is 11 feet.
6. The maximum width traffic lane is 12 feet.

E 412.22 Lane Arrangements: In general, when no other considerations are given, major and secondary highways are divided into three equal standard width lanes in each direction. Right-turn flares and medians with left-turn pockets should be provided at the intersections. See Section E 460. When initiating or designing a street improvement, it is important to make every effort to secure sufficient roadway width to meet the above standards.

Since ideal conditions are not always attainable, it is necessary to consider the optimum arrangement of standard and substandard width lane combinations for a given set of traffic conditions and a given roadway width. For example, for undivided highways or streets that do not have median strips and that permit high-speed traffic flow or have sinuous alignments, the widest lane should be placed nearest the street centerlines. The wider lane provides a safety margin between lines of traffic moving in opposite directions.

For streets having median strips, or for those streets where only slow-moving traffic is expected, such as in downtown business districts, the widest lane is generally placed nearest the curb for the following reasons:

1. The wider lane facilitates the flow of traffic, since it is more difficult to judge the clearance between barriers, such as curbs, on the vehicle's right side than on its left side.
2. The wider vehicles, such as busses and trucks, are usually directed toward use of the lane nearest the curb.
3. The wider lane helps to reduce the conflict between moving traffic and parked vehicles.

For examples of various lane arrangements, refer to Figures E 464.2A, B, and C.
The criteria for pavement cross-sections are considered from two aspects: the geometric section, which involves the shape or crown given to the pavement, and the structural section, which deals with pavement and pavement support.

**E 420 PAVEMENTS**

It is possible to get approximately the same results obtained with the above quadratic equation by using a linear equation. The deviation will not be more than 0.01 foot over the entire range of street widths. The use of this linear equation is acceptable and may be used instead of the above equation in determining the crown value. This formula is:

\[
C = 0.006W + 0.10
\]

See Figure E 421.1B.

For example, using a width (W) of 36 feet, the value of the crown (C) is \(0.006(36) + 0.10 = 0.316'\) or say 0.32'. The value of the radius curve that approximates the parabolic curvature is determined by the formula \(R = 20W - 200\), and the radius that may be used for laying out the parabolic curve for the above example would be \(R = 20(36) - 200 = 520'\).

A table of values has been provided for various width highways. See Figure E 421.1B. The table includes the corresponding radius, crown, or T section to be used. It also indicates how to calculate the elevation at any point on the parabolic crown surface.

Figures E 421.1A(1) and (2) show methods of detailing the elevations of the pavement surfaces for various cross-sections.

Another common practice for designating parabolic curved crown surfaces is the use of the T section. A T section is a particular type of parabolic curve in which the letter “T” followed by a number designates the crown height in inches. For example, T-3 and T-4 correspond to crowns 3 inches and 4 inches in height, respectively. In computing T sections, the total street crown \(C\) is determined either by formula or from the chart on Figure E 421.1B.

When \(W\) is 36 feet or less, a single T section may be used for the full width of the street. If \(W\) is greater than 36 feet, two T sections, each equal to \(\frac{1}{2} W\) in width, should be used. In this case, the total crown \(C\) will determine the elevation \(E\), and the sum of the crowns for the two one-half-width T sections should equal one-half the total crown. See Figure E 421.1B. The crowns on the

---

**E 421 GEOMETRIC CROSS-SECTION**

Street pavements are provided with cross-slope in order to confine the flow of water along a street in a relatively narrow channel. The rate of cross-slope should be sufficient to remove surface waters quickly, yet the pavement should not be inclined to such an extent that drivers are conscious of it.

There are three different basic pavement shapes: the parabolic or T section; the V section; and the inverted V or tent section. Parabolic crown sections or T sections (special parabolic sections) are generally used on the surfaces of most City streets. Inverted V sections are generally used on freeways and limited access highways. V sections are used in alleys. See Section E 610, Alleys. When circumstances so dictate, it is sometimes necessary to use a combination of plane and curved surfaces.

**E 421.1 Parabolic Crown Sections:** The advantage in using parabolic crown sections is that the lane areas normally used for vehicular travel are relatively flat and the cross-slope steepens toward the edge of pavement, thereby facilitating transverse drainage toward the curb. The disadvantage is that parked vehicles or moving cars in the lane adjacent to the curb feel the effect of the steeper cross-slope, particularly where this slope acts adversely to vehicular turning movements on curved alignments.

To determine the parabolic crown, assuming a 2.5-percent slope over the 10-foot-width lane adjacent to the gutter (this is slightly steeper than the 2.08 percent recommended by AASHO), the general formula is:

\[
C = \frac{W^2}{160(W-10)}
\]

where \(C\) = Crown in feet

\(W\) = Width in feet of the parabolic section

See Figure E 421.1B.
two one-half-width T sections need not be equal, provided that their sum equals one-half the total crown.

E 421.2 Special Sections: Normally in industrial areas, standard street cross-sections are used, as in other locations. However, if the street is not expected to carry much water, consideration may be given to a full-width pavement between property lines. In such a case, longitudinal gutters not less than 4 feet wide are provided. The centerlines of these gutters are located along both theoretical curb lines. The longitudinal gutters are constructed as per Figure E 431.1. A V type cross-section for the entire width of street with a center gutter is not permitted. Where the entire surface is concrete pavement, longitudinal gutters may be provided that are equivalent to the above type of gutter in dimensions and width by warping the concrete in the gutter area and forming "V" depressions along the theoretical curb lines. See Figure E 421.2, below.

E 422 PAVEMENT DESIGN (STRUCTURAL)

Modern roadways are surfaced with two types of pavement: rigid and flexible. Criteria for the design and use of these two types of pavement are present in the following discussion.

E 422.1 Flexible Pavements: These pavements have sufficiently low bending resistance to maintain intimate contact with the underlying structure, yet have sufficient stability to support the traffic. Examples include all bituminous types not supported by a rigid foundation.

E 422.11 Flexible Pavement Design: The R-value method of flexible pavement design presented here is substantially the same as that used by the State of California Division of Highways. This is not an attempt to explain the theory behind the method, but instruction in how to use it. The R-value method considers three variables to arrive at the thickness of the structural section:

1. Traffic
2. Resistance value of the soil (R-value)
3. Slab strength (gravel equivalent factor).

Figure E 422.115B enables the engineer to arrive at a total equivalent thickness of gravel (G.E.) to support the design traffic load over the soil in question. The gravel equivalent factor enables the engineer to reduce the total thickness of gravel by replacing it with other materials in the structural section. The following discussion and examples illustrate the use of Figures E 422.114 and E 422.115B for arriving at a structural section.

E 422.111 Traffic Evaluation: For pavement design purposes, the traffic load is expressed as the traffic index (T.I.). For streets classified as major and secondary highways, and for some select system streets, the traffic index to be used for design is determined from Figure E 422.115A.

When estimating the average daily traffic (ADT) for the given design life, the present ADT is increased to account for increasing traffic volumes. The percentage of trucks, which may also be expected to change, can be determined from manual counts. The Department of Traffic provides traffic counts on most secondary and major highways. A number of streets for which traffic counts are available also have manual counts from

---

![SPECIAL SECTION FOR INDUSTRIAL STREETS](image)

Figure E 421.2
which the percentage of trucks and busses can be
determined.

For local streets and alleys, the traffic index
will be estimated according to the type of facility.
See Figure E 422.111, below.

<table>
<thead>
<tr>
<th>TRAFFIC INDEX</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE OF FACILITY</td>
</tr>
<tr>
<td>Minor residential streets, cul-de-sacs</td>
</tr>
<tr>
<td>Average residential streets</td>
</tr>
<tr>
<td>Residential collectors</td>
</tr>
<tr>
<td>Commercial alleys, and primary collectors providing for movement between residential collectors</td>
</tr>
<tr>
<td>Secondary highways</td>
</tr>
<tr>
<td>Major highways</td>
</tr>
</tbody>
</table>

The engineer must use judgment in estimating
the traffic index for streets in industrial and man-
ufacturing areas. These streets may carry light
traffic volumes, but may have a large percentage
of trucks. The heavier loads are many times more
destructive than the lighter loads on a residential
street and may damage the pavement in a rela-
tively short time.

E 422.112 Soil Evaluation: The resistance value
(R-value) of the soil is a measure of the soil’s
ability to resist lateral deformation when sub-
ject to a vertical load. Measurement of the R-
value is made with the soil sample at full moisture
saturation. The testing procedure also considers
some soils to be expansive. The R-value should
be used for flexible pavement design.

If the results of past soil tests on adjacent proj-
ects indicate that the soil properties (Atterberg
Limits, clay content, and R-value) are uniform
over the area in question, the soil properties for
the proposed project can be estimated to have the
same resistance value as that of the adjoining
projects. The engineer should use judgment in
estimating the R-value. When this value cannot be
estimated, tests should be requested from the Bur-
eau of Standards. The traffic index should be pre-
determined and sent with the request, because the
T.I. is used to compute the R-value when the soil

is expansive. To simplify the computation and pro-
vide an added safety factor for the expansive R-
value, the Bureau of Standards will use a gravel
equivalent factor (G.F.) of 2.0. For a full expan-
ation of the R-value test, see Section E 020F(5e),
Test Method No. Calif. 301.

E 422.113 Required Soil Information: When
the R-value cannot be estimated, the designer
should obtain the following soil test information:

1. Atterberg Limits (liquid limit, plastic limit,
   and plasticity index)
2. Mechanical and hydrometer analysis (clay
   content)
3. Resistance value.

The above information should be retained in a cen-
tral file and used for estimating the R-values of
future projects in the area.

E 422.114 Slab Strength: The term strength
means the tensile strength or cohesion of the ele-
ments of a pavement section. This strength gives
the pavement section the ability to act as a slab,
which serves both to reduce the pressure on the
subgrade through beam action and to restrain the
upward movement of the soil around the loaded
area.

The effect of slab action is accounted for by
the gravel equivalent factor (G.F.). The gravel
equivalent factor for asphalt concrete is 2.0. Each
inch of AC is therefore equivalent to 2 inches of
gravel. The gravel equivalent values have been as-
signed to the various materials and are tabulated
in Figure E 422.114, below.

<table>
<thead>
<tr>
<th>GRAVEL EQUIVALENT FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE OF MATERIAL</td>
</tr>
<tr>
<td>Asphalt concrete</td>
</tr>
<tr>
<td>Cement-treated base</td>
</tr>
<tr>
<td>Lime-treated base</td>
</tr>
<tr>
<td>Crushed aggregate base (CAB)</td>
</tr>
<tr>
<td>Untreated base material (other than CAB)</td>
</tr>
</tbody>
</table>

Any thickness of material above can be converted
to an equivalent thickness of gravel (G.E.) by
using the gravel equivalent factor of the material in question. For example:

\[
\text{Thickness of cement-treated base in inches} \times \text{G.F.} = \text{G.E.}
\]
\[
6'' \times 1.5 = 9'' \text{ G.E.}
\]
where G.F. = Gravel equivalent factor
G.E. = Equivalent thickness of gravel.

E 422.115 Structural Section Design Examples:

Problem A: Design the structural section for Main Street between the Santa Monica Freeway and Washington Boulevard.

Traffic Evaluation:

\text{Given: Manual traffic count} = 15,000 \text{ ADT, 10\% trucks, design service life} = 20 \text{ years.}

\text{Solution: Use Figure E 422.115A and following values: 25,000 ADT (estimated 10-year increase) and 10\% trucks.}

\text{Read: T.I.} = 10.

Soil Evaluation: From soil tests, R = 35.

Design:

Determine the gravel equivalent. Use Figure E 422.115B and the above values: T.I. = 10, R = 35.

\text{Read: G.E.} = 25'' \text{ total.}

Assume it is desired to place 8'' AC on CAB.

The CAB gravel factor = 1.1.

The CAB required is:

\[
\frac{\text{G.E. (total)} - \text{G.E. (AC)}}{\text{G.F. (CAB)}} = \text{CAB in inches}
\]
\[
\frac{25'' - 16''}{1.1} = 8.18'' \text{ (use 8'')}
\]

Design section = 8'' AC on 8'' CAB.

Many situations allow comparison of several structural sections, each of which meets design criteria. The cost of each alternative should be considered for availability of materials, future maintenance, and other special conditions which may exist for the particular project.

Some alternate sections for the above design problem are:

- 8'' AC on 6'' cement-treated base
- 8'' AC on 9'' select natural material
- 12'' AC with no base.

Problem B: Design the structural section for 53rd Street between Central Avenue and Avalon Boulevard.

Traffic Evaluation:

\text{Given: 53rd Street is a residential collector.}

\text{Solution: From Figure E 422.111, T.I.} = 5.

Soil Evaluation: Tests adjacent to the project show that R = 42.

The soil in this area has been found, from previous testing, to be uniform. Therefore, assume for design purposes that R = 40.

Use Figure E 422.115B and the above values: T.I. = 5, R = 40.

\text{Read: G.E.} = 12'' total.

Assume the use of asphalt concrete with no base.

\[
\text{AC in inches} = \frac{\text{G.E.}}{\text{G.F.}} = \frac{12}{2} = 6'' \text{ (no base required)}.
\]

An alternate section would be 4'' AC on 4'' select natural material.

E 422.116 Recommended Standard Practice:

1. Minimum thickness of AC:

- Secondary and major highways and commercial 
  alleys = 8''
- T.I. greater than 9 = 8''
- Industrial and manufacturing areas = 8''
- Residential streets and alleys = 4''

2. Crushed miscellaneous material is the highest untreated base material to be required for any project. Minimum thickness when used = 4''

3. Alleys less than 15 feet in width should be paved with portland cement concrete. This is because of inadequate clearance for the equipment used to compact AC.

E 422.2 Rigid Pavement Design: Rigid pavements are composed of portland cement or any other type of pavement laid on a portland cement concrete base. Because of their high bending resistance, rigid pavements can distribute loads over a comparatively large area of the foundation soil.

Where the soils are relatively nonplastic, concrete pavement may be deposited directly on the foundation soil and result in a minimum of bridging effect. Where the soils are plastic, select material base should be applied to act as a buffer between the rigid pavement and the flexible supporting soil. This will effectuate a reduction in the area...
of pavement bridging and excessive pavement pumping action, and will minimize pavement cracking.

E 422.21 Where Concrete Pavement Is Used: There are certain cases in which portland cement concrete is used in City streets:

1. Where the petitioners in a proposed assessment act project specifically request concrete pavement.

2. Where existing concrete pavement is removed and replaced.

3. In streets and alleys with a rate of grade exceeding 20 percent.

4. In alleys less than 15 feet in width. (This is because of inadequate clearance for the mechanical equipment used to compact asphalt concrete. The AC has to be hand-tamped around utility poles, fences, etc. Hand-tamping is a slow process and increases the labor costs.) The use of AC or PCC pavement is optional with alleys 15 feet or wider.

A careful economic study and comparison should be made in each situation to determine whether the use of rigid rather than nonrigid pavements is justified. Particular attention should be paid to the possibility of future utility installations or maintenance requirements which would necessitate removal of the pavement.

E 422.22 Concrete Pavement Thickness: The minimum thickness of concrete pavement to be used in roadways is 6 inches. This thickness would normally be sufficient for major and secondary highways of medium traffic loads—equivalent wheel load (EWL) of 6-8 millions. The use of concrete pavement 8 inches thick should be considered for major and secondary highways of heavy traffic loads—EWL of 8 million and over—and in areas zoned for heavy industry and subject to heavy truck loadings. The maximum thickness of concrete pavement is 9 inches.

E 422.23 Concrete Pavement Removal: Removal and reconstruction of concrete pavement is expensive and should be avoided as much as possible. However, any existing improvements should be removed to a reasonable extent to provide a smooth, neat appearing join section.

When concrete pavement is removed, the removal should be extended to the nearest joint so that no small “floating islands” of concrete remain.
Curbs and gutters are used to:
1. Define the roadway;
2. Control access to adjacent properties;
3. Protect vehicles, pedestrians, and private property;
4. Assist in orderly roadside development;
5. Channelize traffic flow;
6. Control drainage.

E 431 STRUCTURAL TYPES AND USES

The structural types of curbs used depend on the proposed curb location, the type of anticipated traffic, and drainage and economic considerations. The curb types may be further classified as to permanent or temporary use; barrier or mountable; and formed, rolled, or extruded.

E 431.1 Permanent Curbs: Permanent curbs of the barrier or the mountable type are constructed of portland cement concrete. There are two types of barrier curb. One type is constructed by pouring the PCC into prepared forms on an unimproved portion of the street; the details of construction of the Permanent Barrier Type “A”, “B”, and “C” are shown on Figure E 431.1. The other type is constructed by extruding the PCC directly onto the existing pavement surface. Typical sections of the permanent extruded and mountable type curbs are shown on Figures E 431A and E 431B.

E 431.11 Barrier Curbs: Curbs that prevent or tend to prevent vehicles from mounting them are referred to as barrier curbs.

E 431.111 Type “A” Light Curb: This is used for hillside and residential areas where only low volumes of vehicular traffic are expected. It is usually constructed abutting the existing gutter or, when constructed with new gutter, is not poured monolithically with the gutter. It is not desirable to use this curb where dry-weather flow is anticipated unless concrete gutter is also provided.

E 431.112 Type “B” Heavy Curb: This is of heavier construction than Type “A” Light Curb and may be used on streets subject to high volumes of vehicular traffic. It is also used for median stripes and channelization islands. As with Type “A” Light Curb, concrete gutter should be used with Type “B” Heavy Curb where dry-weather flow is anticipated.

E 431.113 Type “C” Integral Concrete Curb and Concrete Gutter: Type “C” Concrete Curb poured integrally with concrete gutter or concrete pavement is normally used for most street improvement projects. This type of curb is constructed more economically than the separate construction of curb and gutter. In addition, it forms a more stable unit against vehicular impact and seepage of dry-weather flow under the curb and gutter.

E 431.114 Extruded or Doweled Curbs: Doweled or glued curbs, extruded curbs, or a combination of these types of concrete curbs may be placed directly on existing pavement. See Figure E 431A. Type “C” or “D” (mountable) may be used for doweled curb. See Figure E 431B. Since this type of construction makes it unnecessary to remove the pavement, it is particularly suitable and economical for construction of medians, strips and traffic islands. However, before this type of curb is used, a design study should be made to ensure that there is no dry-weather flow and that the existing pavement, grade, cross-section, and crown meet the City’s design standards.

E 431.12 Mountable Curbs: Mountable type concrete curbs should use the Type “C” Integral Curb and Gutter. See Figures E 431B and E 431.1. These curbs have a limited use in City streets. They are generally restricted to landscaped portions of median strips, traffic islands, and shoulders, where they act as partial barriers to normal vehicular traffic and are readily mountable by emergency or out-of-control vehicles. See Section E 462 and Subsection E 657.3, Traffic Islands.

E 431.2 Temporary Curbs (Berms): Temporary curbs (berms) of either the mountable or the barrier type are constructed of asphalt concrete pavement. Temporary curbs may be used under the following circumstances:

1. Projects where temporary detours are constructed;
2. Half-width streets where removal is anticipated because of future full-width street improvement;
3. Miscellaneous locations, such as temporary transitional curb between curbs of different alignment; at points where permanent type curbs end abruptly; areas where channelization for water or traffic is needed until permanent drainage or traffic facilities are provided; etc.

**E 432 CURB PLACEMENT**

The placement of curbs can generally be determined from Figure E 113, Standard Street Dimensions. There are other considerations, however, such as clearances between the curb face and the face of an abutment, a pier, a column, or other obstruction. Refer to Section E 222, Clearances.

Curb should be offset 2 feet from edge of through traffic lanes. The 2-foot gutter width as normally constructed may constitute the 2-foot curb offset. In special cases in which the available street width is limited, it is permissible to include the gutter width as part of the usable traffic lane width.

Generally, curb positioning should provide the same unobstructed roadway width at intersections, median openings, and undercrossings or overcrossings. See Section E 656, Types of Intersections.

In setting the alignment for curbs, adequate clearance should be provided to prevent encroachment of the back of curb into private property.

**E 433 MISCELLANEOUS CURB DESIGN DETAILS**

Various details of curb design, such as curb face heights, curb return radii, etc., are discussed in this section.

**E 433.1 Curb Transitions:** When transitioning from one street width to another, a transitional length of 10 feet minimum and 50 feet maximum should be provided on local and residential streets. The maximum length should be used for approaching traffic and the minimum length for departing traffic. On major and secondary highways a 30-to-1 taper is desirable.

Where curbs end abruptly, curb height should transition from full height to zero inches. This transition should have a minimum curb length of 10 feet for approaching traffic and 5 feet for departing traffic.

When joining curbs with different cross-sections, a distance of 20 feet should be used when transitioning from one type of curb to another. The flow line is held constant to provide a uniform lane or street width, and the curb batter is varied in order to present a smooth, continuous curb face surface.

**E 433.2 Curb Measurements of Horizontal Offsets:** When using a curb with nonstandard or variable batter, the flowlines should be aligned to form a straight horizontal line on the tangent portion of the street alignment. All horizontal offset distances from variable-batter curb should be measured from the flowline. All horizontal offset distances from standard-batter curb should be measured from the top of the curb face.

**E 433.3 Curb Return Radii:** The standard radius for all curb returns is 25 feet. There are circumstances where variations must be allowed. However, in no case should the curb return radius be less than 15 feet (except for alleys) nor more than 35 feet. See Subsection E 432.2.

Curb return radii at each intersection must be considered individually. When major or secondary streets are involved, stress should be laid on the use of a curb return radius that will accommodate required turning movements.

**E 433.4 Curb Face Heights:** Eight inches is the standard curb height for City streets. Unless a higher curb height is required to control drainage, 6 inches may be used in residential streets in hillside areas and in short lengths of street terminating in cul-de-sacs. All curbs used for medians and traffic islands should normally be 6 inches in height.

The desirable minimum curb height is 5 inches, and the maximum height is 9 inches. See Subsection E 664.11, Between Intersections. Curbs less than 5 inches in height are not effective vehicle barriers and do not offer protection to pedestrians. Curbs over 8 inches in height make crossing more difficult for pedestrians, and may also interfere with the opening of the doors of cars parked along the curb.

**E 433.5 Curb Removal:** Existing curb should be removed to the nearest construction joint where feasible. Where this is not feasible, it should be saw-cut to a minimum depth of 1 inch in order to provide a smooth join line. If the existing curb is in poor condition at the proposed join, an additional length of curb should be removed to a point where a satisfactory join can be made.
It is important to prevent dry-weather flow (the overflow of water from common domestic uses, lawn sprinkling, etc.) from spreading over the pavement into the path of moving vehicles. The slippery surface produced by this flow may cause vehicles to skid. In addition, vehicles passing over these wet surfaces may splash water onto other pavement lanes, other vehicles, and pedestrians. Therefore, it is important to confine the water to the area of pavement abutting the curb.

The standard pavement crown section in a level street does not adequately confine this flow to the edge of pavement. In addition, where streets have crossfall or superelevation, any water which may be flowing on the high side of the street will cross over to the low side at the locations where crossfall or superelevation sections reverse directions.

Where the flow is confined to the edge of pavement, experience has shown that asphaltic pavements subject to continuous water flow will rapidly deteriorate. Therefore, concrete gutter designed to the standards outlined in this section is used to confine the water. It will be found that concrete pavement can withstand this erosional force better than asphalt concrete. Moreover, concrete gutter can be constructed to a closer tolerance than asphalt concrete pavement. (This is particularly important on flat grades.) Also, concrete gutters can be provided with a smoother finished surface than asphalt concrete pavement, thus reducing the friction between pavement and water and facilitating the flow.

In urban areas, concrete gutters are generally designed in conjunction with inlets to underground water disposal systems. The spacing of these inlets is set so as to intercept the dry-weather flow and prevent any excess of flow from accumulating and overflowing the gutter. The design of these outlets and underground water disposal systems is a function of the Storm Drain Design Division or the Storm Drain Section.

**E 441 TYPES OF GUTTER**

There are three types of gutter used. One type is a longitudinal gutter and, as previously noted, is placed adjacent to the curb. The second type is also longitudinal gutter, is used in alleys, and is generally constructed along the alley centerline. The third type is a cross-gutter and is placed in a transverse direction to the street, usually at the street intersection.

Figure E 431.1 and the Standard Plan Low Flow Channels for Cross-Gutters show details of construction and design for the types of gutter used in the City.

**E 441.1 Longitudinal Gutter (Adjacent to the Curb):** In addition to its use for drainage control, the longitudinal gutter is placed against the curb for construction purposes. The width of concrete gutter separates the curb from the asphalt concrete pavement. This clearance enables a pavement roller to compact the edges of the asphalt concrete pavement more efficiently and eliminates roller damage to the curb.

Except where existing curb is to remain in place, concrete gutter should always be constructed integrally with proposed curb. Normally, concrete gutter is constructed 2 feet wide.

Concrete gutter may be omitted from projects where temporary detours are constructed, and from hillside projects where temporary asphalt berm has been permitted for use in lieu of concrete curb.

**E 441.11 Transverse and Longitudinal Gutter Slopes:** Gutters placed against curbs are constructed with transverse and longitudinal slopes. These slopes confine and direct the water to predetermined disposal points. The criteria for these slopes are as follows:

**E 441.111 Transverse Slopes:** Normally, the transverse slope of the gutter is designed to drain toward the curb. The exceptions to this are channelization islands and median strips. If, because of the landscaping of these traffic devices, there is no irrigation or dry-weather flow generated, 1-foot-wide gutters may be used. These gutters are constructed in the plane of the pavement and may be sloped so that drainage is away from the curb. However, in such a case the gutters would be constructed to facilitate construction rather than for drainage purposes.

The standard transverse gutter section when draining toward the curb should slope as follows:
1 inch of slope for a 1-foot-wide gutter,

1½ inches of slope for a 2-foot-wide gutter,

2 inches of slope for a 3-foot-wide gutter.

The maximum slope for gutters 2 feet or less in width is 8½ percent. The maximum slope for gutters 3 feet or more in width is 7 percent. A minimum slope may have to be used when reconstructing existing gutter or constructing new gutter in existing improved streets having extremely flat pavement crown sections. Although there is no minimum transverse slope limitation, slopes less than standard greatly reduce the gutter’s confining effects on drainage. The maximum slopes are used when reconstructing existing gutter or constructing new gutters on existing improved streets having higher than standard pavement crown sections. If the maximum gutter slope is exceeded, the confining of the drainage in the gutter is increased. However, the resulting excessive hike-up at the outer edge of gutter, if occurring at a driveway entrance, may result in a vehicle scraping its undercarriage in traversing the driveway. See Section E 664, Grade Determination (Street Resurfacing and Reconstruction).

E 441.112 Longitudinal Slopes: It is very difficult to construct concrete gutters with extremely flat longitudinal grades without creating some local flat areas or sumps. Therefore, the minimum longitudinal gutter slope to use is 0.200 percent. At the discretion of the office engineer, the absolute minimum longitudinal gutter slope that is permitted is 0.150 percent. Gutter grades of less than 0.150 percent cannot be constructed to drain satisfactorily. Where the existing conditions are such that a gutter grade of less than 0.150 percent would have to be constructed, the gutter grade would have to be redesigned. Various methods for redesigning the gutter are suggested in Section E 530, Design Policy; Section E 660, Remodeling Improved Streets; and other sections of this Part of the Manual.

E 441.113 Hydraulic Capacity of Gutter: The average ⅝-inch-diameter garden hose 75 feet long will discharge approximately 10 gallons per minute under a head of 40 pounds per square inch. Assuming this represents runoff or dry-weather flow, the hydraulic capacity of a standard 2-foot-wide gutter on various longitudinal slopes is as shown in Figure E 441.113, below:

<table>
<thead>
<tr>
<th>FOOT PER FOOT</th>
<th>CUBIC FEET PER SECOND</th>
<th>GALLONS PER MINUTE</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>

When the dry-weather flow exceeds these values, either the slope should be increased or a storm drain inlet should be constructed to prevent gutter overflow.

E 441.114 Warping Gutters at Drainage Structures: The concrete gutter surface is usually warped at the area of the entrance of drainage structures. This warping accelerates the flow and is a more efficient means of directing the water into the side-opening basins than standard gutter construction.

A local depression (LD) is not to be used on major traffic streets. It may be occasionally justified on purely local residential streets under special or unusual conditions.

Referring to Figure E 441.114, the various design criteria are shown for warping the concrete gutter at a side-opening catch basin and remodeling the adjacent pavement. The width of the warped area should not extend beyond the outer edge of gutter, or in a concrete paved street, not more than 2 feet from the curb line.

In constructing a warped gutter, additional pavement beyond the periphery of the warped gutter area should be removed for streets with existing AC pavement to provide space for forming the concrete. See Figure E 441.114, Cases I and II. Additional pavement removal is not necessary for those portions of the proposed warped gutter area that would abut existing concrete gutter or concrete roadway. However, in order not to exceed the values for the various design criteria for warped gutter (as shown in the figure) and to
provide a smooth grade in both a longitudinal and a transverse direction, it may be necessary to remodel the pavement beyond the limits of the warped gutter construction.

For grating catch basins without warped gutters, the curb face at the grating should not exceed the normal curb face plus 1 inch. At driveways with a 1-inch curb face, the top of the grating should not be set more than 1 inch below the finished surface. In cases where the depressed driveway curb face exceeds 1 inch, the difference in elevation between the top of grating and the top of the depressed curb should not exceed 2 inches.

E 441.2 Longitudinal Gutter (Not Adjacent to the Curb): A longitudinal gutter is used without curbs in locations where curb is not required, such as in some industrial streets and most alleys. See Subsection E 421.2; the figures for Section E 610, Alleys; and Figure E 431.1.

The standard longitudinal gutter is 2 feet in width. The cross-section and other construction and design details are shown on Figure E 431.1.

The information concerning maximum and minimum transverse and longitudinal slopes in Subsection E 441.1 applies here as well.

E 441.3 Cross-Gutters: Subsurface drainage disposal systems are not always feasible from an economic standpoint. In such cases, surface drainage that is transferred from the high side to the low side of the street is usually handled by means of cross-gutters. Cross-gutters are generally placed across intersections or at sumps that may be located in the street between intersections. However, cross-gutters should not be located across major or secondary highway intersections. Two types of cross-gutters are used by the City: the Standard Cross-Gutter and the Low Flow Channel.

E 441.31 Standard Cross-Gutter: The Standard Cross-Gutter is useful where dry-weather flow runs intermittently, because the flow is confined to a limited area. However, in order to confine the water, cross-gutter design requires the construction of a dip in the pavement. This design has the disadvantage of creating an uncomfortable effect on the occupants of a vehicle when crossing the dip. In addition, the water carried in the gutter is subject to splashing by these vehicles. The dip in the pavement may be reduced in part by the method outlined in the next section.

E 441.32 Low Flow Channel Cross-Gutter: Some of the disadvantages of the standard cross-gutter have been overcome in part by the use of the low-flow channel cross-gutter. The plan view, cross-section, and other design details of the grooved gutter are shown on the Standard Plan Low Flow Channels for Cross-Gutters.

The grooved area normally carries the dry-weather flow, preventing the water from coming in contact with the tires of vehicles. Where a greater quantity of dry-weather flow is anticipated, the double grooved section is used.

The low flow cross-gutter may in turn create other problems. It sometimes requires excessive maintenance for proper operation. This is because any sediment, silt, or rubbish which accumulates in the groove, particularly on flat grades, reduces or eliminates the water-carrying capacity of the groove. When this occurs, the cross-gutter acts as a standard cross-gutter. Another disadvantage is that narrow-wheeled vehicles such as bicycles, baby-carriages, etc., as well as pedestrians' shoe heels can be caught in the groove.

E 441.33 Cross-Gutters Located at Other Than Intersections: Cross-gutters may be constructed on local streets other than at intersections under the following circumstances:

1. When a sump is located on the high side of the street and cannot be economically eliminated because of the interference of existing improvements.

2. When provisions for subsurface drainage disposal are not economically feasible.

3. When the cross-gutter will be aligned perpendicular or at least roughly perpendicular to the street and there will be sufficient crossfall (at least 0.25% grade) to provide surface cross-drainage.
4. When the low side of the street has longitudinal drainage. When there is sufficient crossfall, the cross-gutter flowline may be provided with a small amount of crown to approximate the existing crown in the street. The effect of this crown in the cross-gutter is to minimize the dip in the street profile at the cross-gutter. See Subsection E 531.32, Rideovers. When there is very little crossfall to provide cross-drainage, it is usually necessary to use a straight grade for the cross-gutter flowline. However, this straight grade increases the dip in the street profile at the cross-gutter vicinity. To reduce the dip, a transition of the street pavement crown sections approaching each side of the cross-gutter will have to be provided by flattening from the normal crown section to the grade of the cross-gutter.

It is particularly important to produce a smooth riding line for cars traversing the cross-gutter, since a driver will not normally expect a sudden dip in the pavement surface at or near the midblock.

A hypothetical design showing cross-gutter in a local noncontinuous street is provided on Figures E 441.33A and B. The cross-gutter is provided in this case because the sump cannot be eliminated. The elevations used on these figures show what the relationship should be between the flowlines, the outer edges of gutters, the street quarterlines, and the centerlines. This design should provide adequate longitudinal and cross drainage and smooth riding lines.

The elevations used at the cross-gutter edges of the quarterlines and the centerline provide a standard 0.03-foot hike-up above the gutter flowlines. However, the gutter hike-up at the corners of the cross-gutter are nonstandard, since a compromise is sought between providing smooth riding lines and controlling the water in the longitudinal gutter or cross-gutter to prevent it from overflowing the corners of the cross-gutters. To provide this compromise, the hike-up at the corners of the cross-gutters may vary between 0.03 foot and 0.06 foot.
The term border, as used by AASHO, designates the area between the edge of the roadway pavement and the property line. This terminology is used to avoid the confusion created by the dual use of the word parkway, which is often used to define the above area as well as the unpaved or planted area between the back of curb and the front of sidewalk.

The requirements for the rounded or diagonal cutoff property lines at each block corner are included in the following discussion, since the area provided is considered part of the border area.

E 451 BLOCK CORNER PROPERTY LINES

All block corners should be provided with rounded or diagonal cutoff property lines. Adequate sight distance at the intersection for both pedestrian and motor vehicle operator may thus be obtained, since construction of buildings or other improvements would not be permitted in this cutoff area. In some cases, the cutoff area may be needed to provide the minimum width required for sidewalk construction. In hillside terrain, the cutoff area may have to be graded to provide the sight distance or the sidewalk area.

On all major and secondary highways, the block corner property line should have a 20-foot-radius curve. On all other streets a 15-foot-radius curve may be permitted. However, where a commercial development is permitted, a 15-foot by 15-foot diagonal cutoff, in lieu of a 20-foot-radius curve, and a 10-foot by 10-foot cutoff, in lieu of a 15-foot radius curve, may be used. In industrial zones, the curves should have minimum radii of at least 40 feet. However, every effort should be made to ensure that property line returns or cut corners are based on the ultimate right of way requirements. This is done in order to indicate clearly the City's intent to improve intersecting streets (particularly major or secondary highways) to their ultimate right of way width. See Figure E 451A.

Some block corners in existing rights of way may have existing improvements or terrain which make it economically unfeasible to provide the cutoff dimensions given above. In such cases, it may be necessary to reduce either the radius of curvature or the length of the diagonal cutoff. See Figure E 451B.

E 452 SIDEWALKS

The term sidewalk applies to the portion of the pavement reserved for pedestrian use. A sidewalk is generally aligned parallel to the property line and the roadway. The other pavement reserved for pedestrians is generally aligned perpendicular to the sidewalk. Those portions of pavement traversing the parkway area and providing access to the abutting property or actually located on private property have been referred to as walks, crosswalks, or housewalks. To differentiate between these terms, reference is made to Figure E 452. Pedestrian walk or inner block walk is the term used to describe the inner block pedestrian walks. Crosswalk is the term used to describe the roadway area used by pedestrians crossing the street. Housewalk is the term used to describe the pavement reserved for pedestrians and generally aligned perpendicular to the sidewalk.

E 452.1 Locations: The location of sidewalks is shown on Figure E 113, Standard Street Dimensions. Sidewalks should also be provided on culverts in City street easements and on bridges, including those over open channels and over canyons. However, sidewalks should not be constructed unless a curb grade has been approved and the curb is constructed either prior to or concurrently with the sidewalk.

In new subdivisions, sidewalks should be constructed so that the back of the sidewalk abuts the property line. Where existing improvements such as walls, buildings, etc., abut the property line or encroach within the right of way, it may be impractical to remove these obstructions. In these cases it may be necessary to offset the back of sidewalk one-half foot or one foot from the property line.

Large volumes of pedestrian traffic may be anticipated in commercially zoned areas or near schools, etc. In these cases, the parkway should be eliminated and sidewalk should be constructed across the entire width of border.

Some suggested treatments of sidewalk in which the border widths, corner cutoffs, and back-of-sidewalk offsets from property line may vary as a result of any of the above existing conditions are illustrated on Figure E 451B.
At the discretion of the district or division engineer, sidewalk may be omitted in the following cases:

1. In industrial areas zoned M-3 or less, in which full-width pavement between property lines is proposed.

2. In existing right of way where the terrain or existing improvements make sidewalk construction economically unfeasible.

**E 452.2 Widths:** The width of sidewalk that is used in conjunction with the various street classifications is illustrated on Figure E 113, Standard Street Dimensions. The width of sidewalk is always measured from the top of curb face. Therefore, in making estimates of sidewalk quantities, where the entire border area is paved with sidewalk or where the sidewalk abuts the curb, the one-half foot of width for the top of curb is deducted.

The curb return radius should be adjusted or a property line cutoff should be provided at intersections where there is less than a 5-foot width of sidewalk between the property and the face of curb. See Figure E 451B.

In existing right of way with existing sidewalk, any proposed sidewalk should be constructed to match the width of the existing sidewalk. When joining sidewalk that is abutting the property line, it may be necessary to acquire a right of entry to construct the proposed sidewalk. If this is not readily attainable, the back of sidewalk may have to be offset one-half foot from the property line to avoid encroachment on private property during construction.

**E 452.3 Types of Materials, Thickness, and Construction Practices:** Sidewalks should be constructed of portland cement concrete (PCC) 3 inches thick. New sidewalk to be constructed in line with a new or existing driveway apron should be of the same thickness as required for a new driveway at that location. Regardless of thickness, existing sidewalk in line with a driveway apron may be left in place, provided such sidewalk is in good condition and lies within the prescribed longitudinal and transverse slopes. See Subsection E 452.4.

Sidewalks of asphalt concrete pavement may be used only for temporary construction, and only with the approval of the Engineer of Design. In all cases, the sidewalk should be constructed at least 3 feet wide and 3 inches thick. Reference is made to Standard Specifications (1970 Edition), which has several sections dealing with sidewalk construction practices.

**E 452.4 Sidewalk Design:** One of the design considerations is to enable a plane to be formed by the top of curb, the transverse slope of the parkway, the sidewalk, and the surface at the property line. However, establishing this plane relationship between the property line and the curb is not always possible in hillside areas. The transverse slope, which is normally set at 2% percent, should direct drainage from the property line toward the roadway. The maximum transverse sidewalk slope permitted is 6 percent and the minimum is 1 percent. The maximum longitudinal grade change permitted for sidewalk slopes is 6 percent.

Usually, if the curb grade has been properly established, the sidewalk design will fall within the foregoing prescribed design limits. However, sidewalk design problems may arise where private improvements which either encroach in the right of way or are located on private property and abut the right of way have been constructed subsequent to the establishment of the curb grade. If, in constructing these private improvements, little regard has been given to their relationship to the official curb grade, it may not be possible to provide a smooth join between the proposed sidewalk and the existing improvements. The designer must then decide whether to remove all or part of the private improvements or to change the curb grade and possibly the pavement grade.

In other situations there may be existing trees which may interfere with the sidewalk construction. In this case the designer should consult with the personnel of the Street Tree Division of the Bureau of Street Maintenance. This Division will estimate the probability of tree survival following partial root or limb removal. In some cases it may decide that the tree should be completely removed. If the grading of side slopes is also involved, it may be expedient to check with the personnel of the Bureau of Standards as to the stability of the side slopes. Other related situations are covered under Section E 635, Driveway Design; Section E 670, Realignment and/or Widening of Improved...
The design investigation should include the plotting of a sufficient length of the existing sidewalk profile and alignment beyond the point where it is joined by the proposed sidewalk profile and alignment. This plot will enable the designer to eliminate any abrupt angle points that may be due to changes in horizontal alignment, sidewalk widths, or grades.

When the removal of sidewalk is contemplated, the field observations should include existing sidewalk conditions, probable limits of sidewalk removal, and location of nearest scoring line beyond the sidewalk removal limit. Whenever it is practical to do so, sidewalk should be removed to the nearest scoring line.

**E 452.5 Sidewalk Design at Intersections:** After a curb return grade has been established, a profile of the proposed sidewalk should be plotted. Normally, the sidewalk grade closely follows the curb grade. Only a short portion of the front and back of the intersecting sidewalks need be plotted. A smooth line should result when the profiles are plotted through the front and back sidewalk points of intersections (PIs) and extended to the points at which they intersect the top of the curb. In large intersections with extensive sidewalk area, plotting one or two radial sections to check for smooth grades is justifiable. Only in unusual circumstances should the curb return grade be adjusted instead of the sidewalk grade.

A similar procedure is followed where an existing curb return requires replacing by a new curb return. If there is any significant difference in grade between the two returns, all or part of the existing sidewalk within and at the vicinity of the intersection may have to be removed and replaced. The amount of sidewalk to be removed can be determined by plotting various test profile lines of the existing sidewalk. The proposed curb grade is then superimposed at the points where the existing sidewalk profile intersects the new curb. Enough of the existing sidewalk is removed to permit construction of a new sidewalk with a smooth grade, and to connect the remaining existing sidewalk and the top of the new curb grade.

**E 453 PARKWAYS**

The parkway is the unpaved area between the sidewalk and the curb. This acts as a buffer space between pedestrian and vehicular traffic. In many cases, parkway areas provide space for the installation of surface and subsurface utilities. A minimum border width of 9 feet is necessary where the division or district engineer requires installation of trees and tree wells in the parkway.

In substandard width rights of way or on some hillside streets, the space allotted to sidewalk and pavement may limit the width of the parkway to less than 30 inches between curb face and front of walk. Under these circumstances the parkway should be paved to provide continuous sidewalk between the curb and the property line. A parkway should always be graded or paved so that it lies in a plane between the sidewalk and the curb.

**E 454 SHOULDERS**

The shoulder is a portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles for emergency use. It is desirable to provide shoulders on all heavily traveled roadways. However, because of the high cost of land and heavy pedestrian use, it is not practical to use them in urban highways. They are always used on freeways, but they should also be used on major and secondary highways in rural areas and on bridges and other structures.

Where shoulders are used, the normal width of shoulder should be carried throughout the entire project length. These shoulders should be paved sections similar to parking lanes on major streets but should be reserved for emergency use.

On some arterial highways, it is desirable to provide mountable shoulder curbs at the edge of the traveled roadway. These curbs assist in the delineation of the through pavement, form an essential part of the surface drainage system, function as a transition strip between pavement and shoulder, and reduce shoulder maintenance.

When flush with the pavement, shoulders should be pitched sufficiently to remove surface water from the pavement areas, but not so steeply that vehicular use at anticipated speeds is hazardous. The normal slope for paved shoulders is $\frac{1}{4}$-inch per foot. On the high side of superelevated sections or where the shoulder slopes in the opposite direc-
Where shoulders are required, the minimum width should be 8 feet. When drainage requirements dictate, and when additional right of way is available, the width of shoulders may be wider than 8 feet.
A median is a portion of a divided highway separating the traveled ways for traffic in opposite directions. It is an essential and an intrinsic part of freeways and limited access highways, and a desirable element of major streets.

**E 461 USE OF MEDIANS (GENERAL)**

Medians provide effective access control and act as buffers between vehicles moving in opposing traffic lanes. The median strip divides the pavement into two separate roadways. These roadways may be treated independently of each other within limits. The grades of each roadway should be adjusted to reduce excessive crossfall and adverse superelevation, and should be warped to meet varying conditions.

Medians provide refuge for pedestrians crossing wide streets, strategic locations for traffic signs and signal installations, and areas on which piers for structures can be located. They also provide space for disabled vehicles and a lane for emergency vehicles.

Medians of sufficient width provide protection for vehicles stopped within a median opening. This is very effective for vehicles making U-turns at intersections and for vehicles crossing the highways.

Where intersections are at grade and left turns are permitted, these median openings are also used for left-turn movements. See Section E 464. Where possible, installing landscaping in addition to or in lieu of pavement will enhance the appearance of the street and the area.

City streets in the highly urbanized areas of Los Angeles present few opportunities for the use of medians. They have been used on a few limited-access highways, on major and secondary highways, and on some extra-wide streets. The main opportunity for their use at present has been in the utilization of the abandoned railroad right of way strips that are generally located along the centers of streets. Some short strips are used at or near strategic intersections to protect traffic signals, signs, pedestrians, etc. Their future use is anticipated as major and secondary highways are widened and as highways are built through the relatively undeveloped mountainous areas.

**E 462 TYPES OF MEDIANS**

Medians are generally outlined by either painted strips, raised pavement markers, or mountable or barrier type concrete curbs. Each type has specific uses, advantages, and disadvantages. Special or individual problems may be solved by combining types to make use of the advantageous and eliminate the disadvantageous characteristics of each type.

**E 462.1 Painted Medians or Pavement Markers:**

Areas reserved for the median strips may be outlined by means of a reflectorized type of painted stripe or raised pavement markers. Striping is generally painted directly on the pavement surface. This type of median is normally installed by the Department of Traffic and is the one most widely used in City streets.

**E 462.11 Advantages:** Painted stripes or markers are the most economical from both construction and a maintenance standpoint. Emergency and disabled vehicles have easy access for using a painted or marked median as a moving lane or for temporary storage. If any changes in the painted outline are necessary, it is simply a matter of sandblasting or removing the existing stripes or markers and restriping or remarking in the new location.

**E 462.12 Disadvantages:** The main disadvantage of a painted median is that it does not offer any physical restraint to vehicular crossing, and consequently does not adequately protect pedestrians, traffic signals, or signs located in the strip area. On rainy nights the painted lines are difficult to see.

**E 462.2 Curbed Medians:**

Median strips may be outlined by construction of raised barrier or mountable type of concrete curbs. Barrier curbs for curbed medians should normally be Type “C” Integral Concrete Curb with 1-foot-wide concrete gutter. Normally, the structural, grade, and geometric aspects of median design are handled by the Bureau of Engineering with the Department of Traffic supplying traffic data and acting in an advisory capacity.

**E 462.21 Advantages:** Where left turns are prohibited, or where other facilities may attract illegal left turns, the barrier type curb is used. This
prohibits crossings at other than predesigned locations. The deflective action of such a curb helps prevent collision of vehicles with piers, traffic signals, or other structures that may be constructed on the median strip area. It acts as a more positive barrier or buffer between opposing lanes of traffic. It may be used to separate the roadways so that they may be designed with a relative degree of independence of each other.

**E 462.22 Disadvantages:** Medians with barrier type curbs are not readily accessible to emergency or disabled vehicles. The cost of their construction and maintenance may be higher. Any changes in a curbed median layout are more expensive than those in the painted or marker type median. Curb acts as a barrier for drainage and sometimes creates drainage disposal problems. Although the deflecting action of raised barrier curbs decreases opposing traffic accidents, it tends to increase accidents between vehicles on adjacent lanes moving in the same direction.

**E 462.3 Mountable Curbed Medians:** When barrier type curbs are called for in front of hospitals, fire and police stations, or any other institutions used by emergency vehicles, the mountable type of curb is generally used. Whenever mountable curb is required on medians, the first 12 feet back from the nose should be vertical barrier type curb followed by a 20-foot-length transition to the sloping mountable curb. The main purpose of mountable curb, of course, is to maintain traversability and still discourage unauthorized vehicles from making illegal crossings.

Mountable curbs are an attempt at a compromise between barrier and painted medians. They overcome only in a small degree the disadvantages of the other two types. They are traversable, and therefore are not as effective a barrier between opposing traffic lanes, nor do they completely discourage indiscriminate vehicular median crossings. They do not effectively protect traffic signs, etc., mounted on the median. They are more costly to construct or relocate than painted stripes, and they also create drainage problems, as do barrier curbs.

**E 463 WIDTH STANDARDS DETERMINATION OF MEDIANs**

The width of a standard median in a major highway in the City of Los Angeles is 14 feet. However, the influence of major and secondary highway capacity studies, available right of way, and related studies which are covered elsewhere in this Part of the Manual should be considered when determining the median width to be used.

The following factors indicate instances in which the median should be designed to a width of 10 feet:

1. Where an existing section of highway with a median strip 10 feet wide is joined by a new, relatively short section of highway, the new median should also be 10 feet wide. This practice makes it possible to maintain lanes at a uniform width throughout the entire length of highway.

2. When winding, high-speed standard width major highways are constructed, a painted median strip 10 feet wide is used. Part of the extra width is then allocated to the outside curbed lane. This extra lane width tends to minimize conflicts between parked and moving vehicles.

Individual consideration should be given to each intersection, and the entire length of the project should be evaluated in order to determine properly whether to use 10- or 14-foot-wide medians. A minimum width of 14 feet is necessary where piers or abutments are to be located on the median strip. The width chosen should provide a minimum of 5 feet of clearance between the face of the structure and the inner edge of the inner painted traffic lane or curb face (whichever applies). The nose of a 14-foot-wide median has a standard width of 6 feet and a minimum width of 4 feet. Any width less than 4 feet may permit vehicles to straddle the island and, in addition, would not be considered wide enough to protect pedestrians, traffic signs, and signal installations. The minimum length of the nose is 24 feet.

**E 464 MEDIAN LEFT-TURN LANES (POCKETS)**

Where streets are sufficiently wide to permit their use, median left-turn lanes will be found to have many advantages in the handling of traffic.

**E 464.1 General:** The purpose of any separated special turn lane is to expedite the movement of through traffic, to provide for and permit the controlled movement of turning traffic, and to promote the safety of all traffic.
At intersections where left turns are permitted, left-turn median channelization will reduce accidents of the following types:

1. Opposing sideswipe
2. Head-on
3. Left-turn
4. Rear-end.

Design considerations or standards for rural areas may be highly inappropriate in the slower-speed, highly congested urban areas.

**E 464.11 Design Factors:** There are many factors or variables to be considered in the determination of the geometric characteristics of left-turn lanes and in their design. The basic factors are:

1. Storage length
2. Deceleration
3. Through-traffic queue
4. Physical geometric limitations
5. Vehicle composition
6. Topography
7. Required parking restrictions
8. Projected land use.

Variable combinations of the above factors may determine the final design length of the left-turn lane.

**E 464.12 Storage Length:** The following are some of the criteria used to determine storage length:

1. A median lane should be of sufficient length to store the number of vehicles that are likely to arrive during any one interval of time in which left turns cannot be made. The interval of time generally used is one minute. For a peak-hour left-turning volume of \( N \) vehicles, the average number of vehicles arriving per minute is \( N/60 \). For some intervals of one minute, the rate may double the average of \( N/60 \) and may be \( N/30 \). Assuming a rate of \( N/30 \) and allowing 25 feet for each arriving vehicle waiting to turn left, the required storage length is:

<table>
<thead>
<tr>
<th>Turning vehicles per hour</th>
<th>30</th>
<th>60</th>
<th>100</th>
<th>200</th>
<th>300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required storage length, feet</td>
<td>25</td>
<td>50</td>
<td>100</td>
<td>175</td>
<td>250</td>
</tr>
</tbody>
</table>

Turning volumes of 200 vehicles per hour usually require design capacity and traffic signal control studies where the volume of opposing through traffic during the same hour exceeds 800 vehicles.

2. Based on peak 15-minute left-turn volume:

\[
L = \frac{\text{Vol. x 2}}{15 \text{ (or cycles/15 min.)}}
\]

3. Based on peak-hour left-turn volume:

\[
L = \frac{\text{Vol. x 2}}{\text{Cycles/hr.}}
\]

4. Rule of thumb, based on 80-second cycle:

\[
L = \frac{1 \text{ ft.}}{\text{Left-turn vehicles per hr.}}
\]

**E 464.13 Deceleration:** Preferably, the length required for deceleration should be in addition to the length required for storage, but for practical design purposes there can be a reasonable overlap. Assuming the approach speed at the entry to the left-turn lane to be 70 percent of the posted speed, the following list provides some lengths required for deceleration while braking at a comfortable rate:

<table>
<thead>
<tr>
<th>70% x 35 mph = 25 mph</th>
<th>130 feet required</th>
</tr>
</thead>
<tbody>
<tr>
<td>70% x 40 mph = 30 mph</td>
<td>170 feet required</td>
</tr>
<tr>
<td>70% x 50 mph = 35 mph</td>
<td>200 feet required</td>
</tr>
</tbody>
</table>

**E 464.14 Through-Traffic Queue:** Vehicles will queue out of a left-turn lane of insufficient length and block the left-hand or number one through-traffic lane. Also, through traffic often will queue back and block the entry to the left-turn lane. The length of a through-traffic queue is very difficult to calculate because of the variables involved. For example, the length of the through-traffic queue will depend upon the difference between the capacity of the signalized intersection under consideration and the capacities of adjacent signalized intersections, which in turn may be variable. Furthermore, varying input volumes are generated by side streets and driveways. Starting delays, straggling pedestrians, and bus operations all contribute to the traffic queue problem. Generally, the longer the traffic signal cycle, the longer the traffic queue becomes. Consideration of through-traffic queue is best accomplished by actual field observations of existing facilities.
E 464.15 Physical Geometric Limitations: Depending upon the traffic operation to be established upon a given street, physical geometric limitations may have an effect upon or dictate the design length or width of left-turn channelization. These limitations, which are particularly characteristic of existing right of way in urban areas, may consist of closely spaced intersections; reduced roadway width (due to the unavailability of additional right of way); required accessibility to midblock parking lots or driveways, etc. In some instances, physical limitations at a given intersection may preclude the establishment of opposing left-turn lanes.

E 464.16 Vehicle Characteristics: The determination of the length and width of left-turn lanes may be quite different if, as in a heavily industrialized area, many of the vehicles consist of large trucks or trucks and trailers. The 25-feet-per-vehicle allowance may not be an adequate standard for length, or the usually acceptable 10-foot width of lane may be inappropriate.

E 464.17 Topography: The gradient of a street can exert some influence on comfortable braking rates. A little extra allowance should be made for downhill deceleration. Also, vertical curvature has a distinct effect in the determination of the length of a left-turn lane. Often, a left-turn lane should be lengthened so that the transition into the left lane does not occur at the summit or the downhill side of a vertical curve.

E 464.18 Required Parking Restrictions: The installation of left-turn lanes will often necessitate curb parking restrictions or prohibitions. The feasibility of the imposition of these parking restrictions will depend upon the property developments at the site and require very thorough investigation along with sound engineering judgment and supporting data, since they will usually generate public and legislative complaints.

E 464.19 Projected Land Use: Consideration should be given to the projected land use of surrounding areas. The development of new residential, commercial, or industrial subdivisions, freeway construction, zone changes, etc., will generate additional traffic and turning movements. Anticipation of this future need may warrant present provision for additional left-turn-lane capacity.

E 464.2 Left-Turn Lane Layout: Figures E 464.2A, E 464.2B (Plate I), and E 464.2C illustrate medians with left-turn layouts, where parking may or may not be restricted. Figure E 464.2B illustrates three methods of laying out a left-turn lane. This type of layout has special application for streets without median strips and those where parking restrictions are to be minimized. The first of these methods is recommended over the other two because the installation of an approach tangent provides better turning characteristics for entering the left-turn lane. Moreover, it also allows for possible future expansion of the length of the left-turn lane. The second and third methods require the least amount of overall length. See also Figure E 464.2B (Plate II).

The following subsections summarize the individual geometric design portions of a left-turn lane. Refer also to the State of California, Department of Public Works, Division of Highways Planning Manual, Part 7; and, in particular, Section 7-406 and Figures 7-406.4A and 4B and Table 7-405.5.

E 464.21 Transition: This transition has been referred to as transition (State), taper transition, or approach transition. Its length may be determined from the following two formulas, Length (L) being Design Speed x Transverse Offset:

\[ L = VW \]  

where \( V \) = Design speed in miles per hour  
\( W \) = Width of median lane in feet (widening on one side of highway)

\[ L = \frac{VW}{2} \]  

where \( V \) = Design speed in miles per hour  
\( W \) = Width of median lane in feet (widening on both sides of highway)

Rule of thumb:

- 30 mph — Use 30-to-1 taper
- 35 mph — Use 33-to-1 taper
- 40 mph — Use 40-to-1 taper, etc.

The City of Los Angeles utilizes a 30-to-1 taper as a minimum.

E 464.22 Approach Tangent: The approach tangent may vary; a recommended minimum would be 40 feet.
E 464.23 Taper: This taper has been referred to as taper (State), transition, reversal, reverse curve transition, and reverse taper (County). The City utilizes simple reverse curves of 175-foot radii and a taper length of from 60 to 90 feet. Occasionally a minimum length of 50 feet is employed. This is usually the shortest length that will permit mechanized painting equipment to be used.

E 464.24 Length: The length of a left-turn lane measured from the legal stopping point at the intersection end of the added lane to the beginning of the taper may range from a minimum of 10 feet to a maximum of approximately 500 feet. Use of a maximum length of 350 to 400 feet is recommended. In the event that there are over 300 left turns per hour or the calculated lane length exceeds 300 feet, consideration should be given to an optional turn lane or a double-lane left-turn pocket. The City also upon rare occasions has employed lengths ranging from 400 to 550 feet. In general, the length of a left-turn lane should be determined solely upon the basis of its individual requirements.

E 464.25 Width: The width of a left-turn lane that may be used is as follows:

<table>
<thead>
<tr>
<th>Width Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute minimum</td>
<td>9 feet</td>
</tr>
<tr>
<td>Desirable minimum</td>
<td>10 feet</td>
</tr>
<tr>
<td>Standard width</td>
<td>11 feet</td>
</tr>
<tr>
<td>Maximum width</td>
<td>12 feet</td>
</tr>
</tbody>
</table>

Gutter clearances may also be added to the above values. In the event that the left-turn lane is confined between raised concrete islands, its minimum width should be 16 feet to allow for vehicle breakdown.

After construction or striping of median left-turn lanes, it can be determined through field observation whether or not left-turn lanes are effective in accommodating all turning movements. Where feasible, changes can be made by removing and reconstructing the median curb or by erasing the existing lane striping by sandblasting, then modifying it to the new required length.

E 464.3 Nonintersection Left Turns: It is sometimes permissible or even desirable to allow left turns other than at intersections. This may be done at mid-block or other points of entry into private property such as parking lots, gas stations, etc. See Figures E 464.2A and E 464.2B (Plate I).

The advantage of permitting nonintersection turns is that it reduces the congestion and conflict at intersections. This is particularly important at busy intersections. However, it should be noted that the conflicts are not necessarily eliminated; they may be merely transferred from the intersection to the mid-block or other points.

E 465 GRADE DETERMINATION OF MEDIANS

Since painted medians are painted directly on the finished surface of the pavement, they are not included in the discussion that follows.

After the length, width, and other design considerations are determined for the median strip, the curb grade should be established. Although the same basic principles apply here as for any curb grade design, there are certain other factors not usually considered in curb design that are considered in median curb design. Refer to Section E 660, Remodeling Improved Streets. For example, where it is intended to superimpose the curb directly on the existing or proposed pavement, a study is made of the finished surface pavement grades. If these grades are smooth and satisfactory in all respects, the median curb will probably also be satisfactory.

When an unpaved section of street, such as an abandoned railroad right of way, or a part of the existing street must be remodeled or resurfaced, the median curb grade design used must fit the existing street conditions. It is sometimes necessary to adjust the median curb grade or the street grade or both in order to achieve a balanced design. In this case, a balanced design would be reached by obtaining a satisfactory median curb grade with a minimum adjustment and remodeling of existing street conditions. See Section E 660, Remodeling Improved Streets.

Median curb grades are affected in cases where the highway is divided into separate roadways. The separate roadways permit relatively independent grade design in relation to each other. The median curb grades provide a transition between the grades of the two roadways. Figure E 465 shows how the design of the median acting as a road divider is gradually transitioned so that as the intersection is approached, the two roadways merge into one section of roadway.
E 466 DRAINAGE CONSIDERATIONS

Construction of a curbed median on streets having a high rate of superelevation or crossfall will result in the interception by the median of the transverse drainage due to the storm water or gutter overflow. Disposition must also be made of dry-weather flow from the irrigation of landscaped medians. See Subsection E 467.3. To dispose of this water, concrete gutters are constructed abutting the median curb. The median gutter should be designed with adequate longitudinal grade, so that the flow continues to a point of surface or subsurface disposal. Although a 1-foot-wide gutter is normally used, a considerable flow of water may require a 2-foot-wide gutter.

The method of drainage disposal used is usually dictated by the availability of drainage facilities. When none of these facilities are available, the engineer may have to resort to intersection cross-gutters. However, although intersection cross-gutters are permitted on local streets, they are not to be used on major or secondary highways. Since most medians are constructed on major or secondary highways, the water generated in these cases should be handled by providing subsurface drainage disposal. If subsurface drainage is not available or economically feasible, items such as irrigated landscaping should be postponed until a storm drain system is installed.

Figure E 466 shows four typical street cross-sections with curbed medians. These sections show how the transverse median gutter section should be tilted, based on a given situation.

“A” shows a level cross-section with no dry-weather flow. Since there is no water to confine, the transverse slope of the median gutter is constructed in the plane of the crown section.

“B” shows a level cross-section with irrigated landscaping that receives dry-weather flow. The median gutter is tilted up to the standard gutter hike-up, so that the dry-weather flow entering the median gutter is confined as it flows longitudinally.

“C” shows a tilted section with no dry-weather flow. The median gutter is constructed in the plane of the crown section for the same reasons as for Section A.

“D” shows a tilted cross-section with dry-weather flow. The slope of the median gutter has a standard hike-up on both sides of the median.

E 467 CROSS-SECTION OF CURBED MEDIAN

The transverse grades and the structural cross-section of the median are included in the following discussion. Other components of the median cross-section are covered elsewhere in this Part of the Manual.

E 467.1 Transverse Grade: In some cases, median strips are used primarily to divide the highways into separate independent roadways. This is generally done because there is a large difference in elevation between the two roadways. When the median is used for this purpose, the cross-sectional grades are not critical. However, the maximum slopes of the median should not exceed 2 to 1 and the minimum slopes should not be less than 1 percent. If the curbs are level, the median cross-section should be designed in the shape of an inverted V, using 2½-percent slopes, to permit transverse drainage. See Subsection E 467.3.

Where medians are subject to emergency vehicular or occasional pedestrian use, the maximum transverse slope should be 6 to 1, although flatter slopes not less than 1 percent are preferred.

E 467.2 Structural Cross-Section: When construction is not over existing pavement, the entire raised surface of median strips should be paved with a minimum thickness pavement of 6 inches of portland cement concrete and 4 inches of asphalt concrete or landscaping. Where Select Material Base is required under the roadway, it should also be placed under the raised median strip surfacing.

Median strips that are constructed by doweling or extruding concrete curb over the existing pavement may have the raised surface paved with a minimum of 3 inches of portland cement concrete pavement. However, where the curbs are constructed directly on the pavement, and where the median strip area is less than 1000 square feet, it may be more economical to fill the space between the existing pavement surface and the raised median surface with solid concrete. Where the median area is more than 1000 square feet it is usually more economical to use a portland cement concrete pavement 3 inches thick and the same sub-
base material as is specified for use under the roadway pavement.

Asphalt concrete pavement is generally used only on a temporary basis, to construct asphalt concrete berm and pave the raised median surfaces. If the existing raised median surface adjoining a proposed improvement has an asphalt concrete pavement, it may be desirable to pave the new construction also with asphalt concrete for esthetic reasons. A minimum thickness of 4 inches is to be used for asphalt concrete pavement.

E 467.3 Landscaping: The following criteria should be used in determining whether areas within the improvement limits are to be landscaped:

1. Council Resolution requirement
2. Petition request
3. Size of area
4. Agricultural suitability of soil
5. Availability of water
6. Availability of electricity
7. Projected maintenance costs
8. Grading Ordinance No. 123,970

If landscaping is proposed, prints of preliminary street plans should be submitted to the appropriate Landscape Architectural Section. The prints are for use in the preparation of the landscaping plans.

Median strips or traffic islands that are constructed with either nontraversable barrier curbs or mountable Type "D" curbs may receive landscape treatment. Some damage to landscaping is expected to occur infrequently, although more often on mountable than on barrier type curbs. The landscape treatment may consist of ground cover, shrubs, trees, or combinations thereof.

Shrubs and trees should not be installed where sight distance may be impaired. Since a water source is required, drainage disposal must be considered. See Section E 466.

In general, median strips less than 10 feet in width or traffic islands with an area of less than 500 square feet may be provided with artificial grass or approved surface treatment. In median strips wider than 10 feet or other areas larger than 500 square feet, either live approved plantings or artificial grass may be installed. Where adequate soil depth cannot be provided economically, artificial grass or an approved surface treatment may be used.

Center medians in underpasses or under bridges should not be landscaped with live plantings. All slopes other than those under bridges or underpasses should be considered for planting with natural or artificial ground cover, shrubs, trees, or combinations thereof.

For drainage purposes, the minimum transverse slopes for median strips and traffic islands having artificial grass is 1 percent. Where the slopes have to be pitched upward from the curbs toward the middle of the island or median strip to form a crowned surface, a grade break is created at the junction of the intersecting grades. The maximum grade break over which the fibers of artificial grass should be installed is 6 percent.

The most practical base for artificial grass is portland cement concrete with a minimum thickness of 2 inches (on a Select Material Base if this is required on the rest of the project). The surface of the portland cement concrete should be a wood float finish. The surface should be ¾-inch below the top of the abutting curb. This permits the fiber base of the artificial grass to fit flush or slightly below the top of curb.
In the process of street design, particularly on hillside projects, the use of bulkheads or retaining walls must sometimes be considered. The need for such structures may be due wholly or in part to some of the following requirements:

1. To correct or alleviate unstable side slope conditions.
2. To avoid exceeding the allowable maximum cut or fill on side slopes.
3. To reduce the amount of earthwork (cut or fill).
4. To reduce excessive right of way costs.
5. To prevent undermining or burying existing improvements.

Based on the above conditions, if it is decided that structural support is necessary, a choice must be made as to the use of bulkheads or retaining walls. Some of the factors that might influence this decision are treated here only briefly, since the decision may be based in part on the advice of the Geology and Soils Engineering Section of the Street Opening and Widening Division and is normally a function of the Bridge and Structural Design Division.

**E 471 GENERAL**

As a rule, wooden bulkheads are used for temporary structures because of their economy, whereas reinforced concrete, metal bin-type, or other types of retaining walls are used for permanent structures. Wooden bulkheads are generally used on streets that are not improved to their ultimate width (half streets) or in unimproved, undeveloped areas. In the latter case, as the abutting property is developed and ingress and egress (driveways, walks, steps, etc.) are provided, bulkhead removal becomes necessary.

Some of the retaining wall design problems caused by space limitations are as follows: Additional right of way may be necessary to construct the footing (or even the entire wall) on private property. Footings may be designed for the dual purpose of supporting the wall and acting as a sidewalk. In other situations enough vertical clearance may have to be provided between the buried footings and the sidewalk to permit installation of utility lines.

Consideration must be given to other factors, such as the construction costs of cut and fill and additional right of way costs. These costs must be compared with the cost of the retaining wall construction and with other connected costs, such as excavation and backfilling.

On hillside streets with steep side slopes, the low side of the street may require a retaining wall to retain part of the street and/or sidewalk. The portion of wall used for retaining purposes may require a height of only 1 or 2 feet. However, in order to provide adequate protection for pedestrians and vehicles, the use of a higher wall is advisable. In these cases, to economize on construction, the wall may be made of a combination of masonry and concrete blocks, or of masonry and chain link fence.

Drainage problems are sometimes encountered because of the total or partial blockage of natural watercourses by retaining walls. In other cases, weep holes in the walls may permit undesirable drainage channels to form because of the pressure created from dry-weather flow.

In order to make a comprehensive design study, the designer must consider all of the above factors. In addition, plans, profiles, and cross-sections showing the relationship of the proposed street grade and alignment to the existing or future ones must be included.
Side slope problems are frequently encountered on hillside developments. There are two basic types of projects. One deals with improving streets in existing rights of way with existing abutting improvements; the other is in undeveloped land. Occasionally a third type of special project is encountered, such as Chavez Ravine, Mulholland Drive, Kenfield Slide Area, etc.

Although the terrain and the situations differ, four main design factors are commonly involved and should always be considered:

1. Adequate engineering and design study
2. Safety
3. Economics
4. Esthetics

When the side slopes require more than 6 feet of cut or fill, a soils report should be requested from either the Geology and Soils Engineering Section of the Street Opening and Widening Division (for City projects) or an approved soil testing laboratory (where private developments are involved). It may then be necessary to make extensive field surveys and to maintain close observation of any unstable conditions that may develop during design and construction.

**E 481 SIDE SLOPE DESIGN REQUIREMENTS**

The general requirements for side slopes, including the treatment of side slope drainage disposal, are thoroughly detailed in the *Los Angeles Grading Ordinance*, No. 123,970. Construction specifications are covered in the *Standard Specifications* (1970 Edition). See Sections E 020A and E 020B. It is suggested that the designer become familiar with the design criteria and specifications in these publications.

To summarize briefly the side slope requirements: Side slopes should not be graded more steeply than 2-foot horizontal to 1-foot vertical for cut and fill slopes. Figure E 481A shows a typical cut and fill slope section and the type of bench used. For hillside construction in existing unimproved streets with existing abutting improvements, the street improvement is often limited to the central portion of the dedicated streets. The grading usually extends on a slope to the back of sidewalks.

![Grading in Back of Sidewalks](image)
property line. Fences and other private improvements abutting the property line may be affected. Where possible, grading should not extend to the property line but should provide at least 1 foot clearance from the property line. A greater distance from the property line to the toe of slope or top of fill may be necessary to protect existing improvements. In any case, grading must be consistent with good engineering practice and economy.

The treatment of side slopes where the roadway or sidewalk is constructed on fill is as follows: Where slope easements are required and the sidewalk is constructed abutting the property line, or where no easements are required but there is space for grading between the back of sidewalk and the top of fill, the grading should be extended at a 1-percent slope to form a hinge point 1 foot back of the sidewalk. See Figure E 481B, below.

The amount of water falling on or carried by this additional foot of grading is negligible. In addition, it drains away from the sidewalk. Therefore, the additional grading serves as a safety factor in the event of even moderate slope erosion and thus minimizes the possibility of undermining the sidewalk.

To determine the maximum inclination to assign to the side slopes, the engineer must consider some or all of the following factors: The type of soil involved, as shown by soil tests; the geological formations; the geographical location; and whether or not excess water, springs, etc., are present in the sidehills. For example, some types of solid rock formations may permit a vertical or nearly vertical cut.

Consideration will be given by the City Engineer to modifying slope requirements where the geological formation, as evidenced by existing cuts, by exploration, or by soil tests, is such as to indicate that steeper slopes would be satisfactory.

When any doubt exists as to the nature, stability, or allowable maximum slopes of the side slopes, it is advisable to confer with staff members of the Geology and Soils Engineering Section of the Street Opening and Widening Division.

E 482 BENCHES AND TERRACES

The main function of benches and terraces is to intercept water flowing down the side slopes and divert it by means of a drainage disposal system. This considerably reduces the volume and velocity of the water hitting the lowest level or bottom of the slope as well as the scouring and erosion of the side slopes. Benches and terraces are also used on side slopes to break up the high cuts and fills into smaller sections. If a section of side slope starts sliding, it may terminate at the next bench or terrace immediately below, rather than continuing down to the bottom and possibly creating an avalanche and a collapse of the entire cut or fill section.

The need for benches and the design of their widths and vertical spacing should be determined only after an adequate soil investigation. In general, horizontal benches 10 feet in width should be constructed on cut and fill slopes at vertical intervals of not more than 25 feet.

E 483 ECONOMIC CONSIDERATIONS

It is very difficult to evaluate the comparative overall costs of flat vs. steep side slopes. The advantages of steep slopes are the smaller volume of earthwork required and the smaller amount of right of way involved. In large cuts or fills it may be more economical to bench than to flatten slopes. On the other hand, the cost involved in stabilizing, planting, and perpetual maintenance may sometimes exceed the cost of grading and right of way required to provide a flatter slope. This illustrates that the steepest slopes permissible are not always the most economical.

Sometimes the most economical solution is to use a retaining wall. A short length of low retaining wall, at a critical section, may eliminate the need for expensive right of way, avoid damage to existing improvements, and considerably reduce the volume of earthwork required.

E 484 ESTHETIC CONSIDERATIONS

Since large expanses of bare exposed slopes are unsightly and are subject to erosion, an effort should be made to cover them with vegetation or synthetic grass. See Subsection E 467.3. The proposed grading of slopes and its effect on adjacent trees and their root systems should be carefully evaluated. If possible, minor local grading modifications should be considered to avoid tree removal. See Section E 671.4, Tree Removal.
When feasible, contour grading should be used on the side slopes to provide a natural appearance. For example, long, uniform cut or fill sections appear unnatural. This effect can be modified somewhat by flattening the slopes on the ends where the cut or fill is light. The slope is gradually steepened as it approaches the controlling maximum slope of the heavier portion of the cut or fill.
In hazardous areas where vehicles which inadvertently leave the highway may be subjected to considerable damage, traffic guides and barrier installations are used. Such areas include steep fill or natural side slopes, steep grades on long through fills, abrupt changes of alignment, sharp curves, dead-end streets, etc. See Figures E 490(1), (2), and (3) for typical installations.

**E 490 TRAFFIC GUIDES AND BARRIER INSTALLATIONS**

When considering these danger areas and other elements, such as high vehicular speed and poor visibility, the more dangerous points along a highway are obvious from the construction plans. From these factors, the type of devices to be used, as well as their location, length, offset, and spacing, can be readily determined. However, the overall need for these installations is best decided by field inspection, since certain hazardous areas may not be evident until the grading nears completion. Installation should be made before the highway is opened to traffic.

The choice of type of installation required is largely a matter of the hazard involved. For example, guard rails are designed to resist impact by deflecting a vehicle so that it continues to move relatively parallel to the guard rail at reduced velocity. However, a vehicle may be deflected onto adjacent lanes into the path of vehicles moving in the same direction. Moreover, any abrupt stop of a vehicle is dangerous, and a guide post or a projection on a guard rail which might snag a moving vehicle is undesirable. The sudden stop may be more hazardous than driving down a slope.

Generally, the need for these protective or warning devices is directly related to the steepness of downhill side slopes. For this reason, they may be omitted where it is practical to provide fill slopes of 4 to 1 or flatter. They should not be omitted where the terrain continues to drop away from the toe of fill even though the slope is 4 to 1 or flatter. Headwalls, interceptor drainage channels, trees, or other objects that may be present on slopes also represent a possible traffic hazard. Basically, wherever there is a potentially hazardous situation, even with flat slopes, guard or warning device installation is usually justified.

**E 491 CHOICE OF LOCATION AND TYPE**

When considering these danger areas and other elements, such as high vehicular speed and poor visibility, the more dangerous points along a highway are obvious from the construction plans. From these factors, the type of devices to be used, as well as their location, length, offset, and spacing, can be readily determined. However, the overall need for these installations is best decided by field inspection, since certain hazardous areas may not be evident until the grading nears completion. Installation should be made before the highway is opened to traffic.

The choice of type of installation required is largely a matter of the hazard involved. For example, guard rails are designed to resist impact by deflecting a vehicle so that it continues to move relatively parallel to the guard rail at reduced velocity. However, a vehicle may be deflected onto adjacent lanes into the path of vehicles moving in the same direction. Moreover, any abrupt stop of a vehicle is dangerous, and a guide post or a projection on a guard rail which might snag a moving vehicle is undesirable. The sudden stop may be more hazardous than driving down a slope.

Generally, the need for these protective or warning devices is directly related to the steepness of downhill side slopes. For this reason, they may be omitted where it is practical to provide fill slopes of 4 to 1 or flatter. They should not be omitted where the terrain continues to drop away from the toe of fill even though the slope is 4 to 1 or flatter. Headwalls, interceptor drainage channels, trees, or other objects that may be present on slopes also represent a possible traffic hazard. Basically, wherever there is a potentially hazardous situation, even with flat slopes, guard or warning device installation is usually justified.

**E 491.1 Uses:** Guide posts, sight posts, and guide markers are primarily used to delineate the roadside direction at sections where many drivers might become confused. Although these appurtenances are not expected to resist impact, the heavy guide posts may prevent slow-moving vehicles from leaving the roadway.

When guard rail is used in hazardous locations, heavy guide posts or heavy sight posts, spaced to permit vehicular access to adjacent property, are substituted for a portion of the guard rail. At points where driving off the road is not highly dangerous, less heavy guide and sight posts and guide markers may be used, so that little damage will be done if they are struck.

Guard rails or guiding devices should be located at a constant horizontal offset from the edge of the pavement. This fixed distance serves as a guide to the driver as to the distance to the edge of the lane or road when visibility is limited. They should be located back from the shoulder line and set at about the same elevation. It is desirable to flare the rail outward for a short distance on the traffic approach end in order to lessen possible direct end impact and to provide a full view to the driver. Usually, only the outside of horizontal curves need be outlined by guide posts or other warning devices.

There is no fixed spacing to be used between posts of the guide or sight markers. However, the more hazardous the situation, the closer the spacing of the guide installations should be.

Reference is made to Figures E 490(1), (2), and (3), and to Figure E 491.1. These figures illustrate some of the typical applications for these devices and provide standards or guides for their installation.

**E 491.2 Placement:** Figure E 490(1), Plate I, shows where guard rail may be omitted on the tangent portion of the horizontal alignment of a normal street section. Plate II shows traffic barriers and warning rails used as protection of pedestrian and vehicular traffic against hazardous hillside conditions. Chain link fence should be used where only pedestrian traffic requires protection. It should also be used adjacent to or in the vicinity of schools, playgrounds, parks, etc.
Where one or more of the minimum slope distance criteria as shown in Figure E 490(2), Plate III, cannot be met, guard rail is required. Where the back edge of the guard post is less than 1 foot from the top of the fill slope, a longer post must be used. This post must be provided with a minimum depth of cover of 2 feet 2½ inches. This cover is measured at a depth where a level line of at least 1 foot of width extends from the back of the post and intersects the slope, as shown in Figure E 490(2), Plate IV.

Figure E 490(3), Plate V, shows a cul-de-sac terminating at the top of a ridge or steep fill. Plate VI shows a street with a sharp horizontal curve. Plates VII, VIII, and IX show a dead end, an abrupt alignment change, and a sudden narrowing of the roadway, respectively.

The placement of these guard or guide devices with respect to the offset from the street centerline, or the X and Y distances from the BC and the EC respectively, and the most probable path of a vehicle as shown on these plates, require the determination of roadway widths, vehicle speed, abruptness of alignment changes, visibility, etc., and the consideration of these factors for each individual case.

In conclusion, use of the metal-beam guard rail with metal posts is suggested for new installations, although the metal-plate and metal-beam type with wooden posts may be acceptable. Generally, the metal-plate type should be used only to replace portions of existing metal-plate guard rail. It is preferable to use metal installations, since wooden barriers and guide posts, such as laminated wooden guard rail or standard wooden warning rail, are not as effective or as durable. The types of installations shown in the City’s Standard Plans or any other type acceptable to the City Engineer may be used. The treatment of any situation not covered by these figures or the City’s Standard Plans, or any deviations from these standards, should be approved by the design office.