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ROADWAY

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CHAPTER 6
ROADWAY

6.00.00 GENERAL PROVISIONS

6.01.00 APPLICABILITY

This chapter contains minimum criteria to be met on all streets and parking lots designed and constructed in the City, both by private land developers and by the City.

6.02.00 VARIANCES

Where any particular minimum requirements contained in this chapter can be shown to be inappropriate when applied to an “out-of-the-ordinary” situation, variances to said minimum requirements will be considered and may be authorized by the City Engineer where the proposed variance in minimum requirements will result in a level of safety, service, and quality equal to or greater than that intended by the application of the minimum requirements.

6.03.00 PRIVATE STREET SYSTEMS AND PARKING LOTS

Private street systems and parking lots shall be subject to all minimum requirements of these STANDARDS AND SPECIFICATIONS except that variances, as provided for in Subsection 6.02.00, will be allowed subject to the review and approval of the City Engineer.

6.04.00 CITY CAPITAL IMPROVEMENT PROJECTS

It is recognized that the minimum requirements contained in these STANDARDS AND SPECIFICATIONS are not necessarily sufficient for plans, specifications, and contract administration purposes for City administered street capital improvement projects. Accordingly, the City Engineer is authorized to develop and/or approve such additional requirements and procedures necessary for bidding, awarding, and administering for such projects, provided said additional requirements and procedures are substantially consistent with these STANDARDS AND SPECIFICATIONS and applicable provisions of other City ordinances and resolutions.

6.10.00 ROADWAY DESIGN AND TECHNICAL CRITERIA

This section sets forth the minimum design and technical criteria and specifications to be used in the preparation of all roadway plans. Within this chapter, " AASHTO "Green Book" refers to "A Policy on Geometric Design of Highways and Streets -- 1990" as published by the American Association of State Highway and Transportation Officials.

6.11.00 REPORTS

6.11.01 Submittal Format

All reports shall be bound in an 8-1/2" x 11" folder and shall include the seal and signature of the Professional Engineer registered in the State of Colorado who is responsible for the report contents. In addition, all reports shall include the following statement:

"We acknowledge that the City of Westminster's review of this study is only for general conformance with submittal requirements, current design criteria, and standard engineering principles and practices. We are also aware of the provisions of Section 11-6-5(B)3 of the City Code of the City of Westminster."

6.11.02 Traffic Analysis Report

All subdivision, Planned Unit Development (PUD), and commercial developments shall require a traffic analysis report giving information and details as may be required by the City Engineer and as specified in Chapter 8 of these STANDARDS AND SPECIFICATIONS.

6.11.03 Pavement Design Report

All roadway construction in the City of Westminster shall require a pavement design report. The report content shall be in accordance with Section 6.30.00 of these STANDARDS AND SPECIFICATIONS.

6.11.04 Pavement Evaluation Report

After installation of the bituminous surface course, except for the final two inchs (2") on residential streets, the developer may be required to furnish the City Engineer with a copy of a report prepared by a Professional Engineer registered in the State of Colorado utilizing non-destructive deflection testing to access and predict the performance of the pavement. This testing may be required if evidence exists that the pavement section may not meet the design specifications. The Professional Engineer shall have a past history and knowledge in performing these tests. Qualifications of Professional Engineers shall be submitted to the City Engineer for approval before the start of work.

The pavement evaluation shall be performed in accordance with good engineering practices. The report shall generally embody the following testing and pavement evaluation techniques:

(A) Environmental Study (Frost Cycle, Drainage, etc.).

(B) Pavement Surface Elevation.

(C) Soil Borings in Areas of High Deflections.

(D) Pavement Deflection Analysis.

The report shall evaluate the existing condition of the base and binder course by performance of deflection tests at one-hundred-foot (100') spacings per traffic lane. Spacing will be

staggered in each lane. The report shall determine whether or not the pavement section will meet a 20-year pavement life or greater.

If the pavement section is not projected to meet a life expectancy of 20 years or more, the report shall propose asphalt overlays in excess of the existing pavement section to bring the new pavement section to a 20-year life expectancy. The City Engineer will evaluate the results of the report and inform the developer of the acceptable solution mentioned in the report.

6.12.00 LOCAL STREET

6.12.01 Local

A local street is a general term denoting a roadway designed or operating with the following characteristics:

(A) **Posted Speed Limit.** Between 25 and 30 miles per hour. Posted or prima facia speeds for the various street classifications are normally five (5) to ten (10) miles per hour less than the design speed of that street.

(B) **Traffic Volumes.** Less than 2,500 vehicles per day.

(C) **Limited Continuity.**

(D) **Safety.** Designed for the safety of pedestrians and bicyclists and the ease of access to adjacent parcels of land.

(E) **Traffic Control.** Stop signs, yield signs, or right-of-way rules for uncontrolled intersections. Traffic requirements in other than residential areas may require special design consideration by the applicant's engineer and the City's Transportation Engineer.

(F) **Function.** Local streets provide direct access to adjacent property. Traffic carried by local streets should have an origin or a destination with the neighborhood. Local streets are utilized in single family residential areas. Utility line easements should be available.

(G) **Right-of-Way.** Fifty three feet (53') with attached walk. Fifty-seven feet (57') with detached walk.

(H) **Number of Moving Lanes.** Two.

(I) **Access Conditions.** In accordance with Chapter 8 of these STANDARDS AND SPECIFICATIONS.

(J) **Planning Characteristics.** Local streets should not intersect major arterial streets.

(K) **Type of Curb and Gutter.** Four inch (4") combination curb, gutter and walk, with attached walk; six inch (6") vertical with detached walk.

(L) **Sidewalk Width.** Five foot (5') minimum, attached or detached from curb.

(M) **Cul-De-Sacs.** In accordance with Section 6.21.00 of these STANDARDS AND SPECIFICATIONS.

(N) **Street Widths.**

1. Thirty foot (30') paved width plus two (2) two foot (2') gutter pans.

6.13.00 COLLECTOR STREET

6.13.01 Minor Collector

A minor collector is a general term denoting a roadway designed or operating with the following characteristics:

(A) **Posted Speed Limit.** Between 25 and 30 miles per hour. Posted or prima facia speeds for the various street classifications are normally five (5) to ten (10) miles per hour less than the design speed of that street.

(B) **Traffic Volumes.** Generally less than 7000 vehicles per day.

(C) **Continuous.** For less than two (2) miles.

(D) **Safety.** Designed to handle traffic volumes loading from and onto local, other collector, and arterial roadways.

(E) **Traffic Control.** Regulation of traffic accomplished through the use of stop signs and channelization. Traffic signals normally use only at intersections with major collectors and arterial streets.

(F) **Driveways.** No back-out drives permitted.

(G) **Function.** Collector streets collect and distribute traffic between arterial and local streets and serve as main connectors within communities, linking one neighborhood with another. Traffic carried by collector streets should have an origin or a destination within the community. Utility easements should be available.

(H) **Right-of-Way Width.** Seventy-feet (70') minimum, eighty-foot (80') average.

(I) **Number of Moving Lanes.** Two (2).

(J) **Access Conditions.** In accordance with Chapter 8 of these STANDARDS AND SPECIFICATIONS.

(K) **Planning Characteristics.** Collector streets should have continuity throughout a neighborhood but need not extend beyond the neighborhood intersections with collectors, major collectors, and arterial streets should be at least one-quarter (1/4) mile apart.

(L) **Type of Curb and Gutter.** Six (6) inch vertical.

(M) **Sidewalk Width.** Five feet (5') minimum. Detached from curb.

(N) **Street Widths.** Thirty-foot (30') paved with two (2) two-foot (2') gutter pans.

6.13.02 <u>Major Collector</u>

A major collector is a general term denoting a roadway designed or operating with the following characteristics:

(A) **Posted Speed Limit.** Between 30 and 45 miles per hour. Posted or prima facie speeds for the various street classifications are normally five (5) to ten (10) miles per hour less than the design speed of that street.

(B) **Traffic Volumes.** Generally greater than 7000 vehicles per day and less than 12,000 vehicles per day, when the land which the collector serves is fully developed.

(C) **Continuous.** For two (2) or more miles.

(D) **Safety.** Designed to handle traffic volumes loading from and onto local, other collector, and arterial roadways.

(E) **Traffic Control.** Regulation of traffic accomplished by signing and channelization. Traffic signals will normally be located only at intersections with streets of higher classification. Parking allowed.

(F) **Driveways.** No back-out drives permitted.

(G) **Function.** Major collector streets permit relatively unimpeded traffic movement and are intended for use on those routes where two (2) moving lanes are required but where a larger classified street is not warranted. Utilized in industrial, commercial, multi-family and single family residential areas, where on-street parking is required.

(H) **Right-of-Way Width.** one hundred four feet (104').

(I) **Number of Moving Lanes.** Four (4).

(J) **Access Conditions.** In accordance with Chapter 8 of these STANDARDS AND SPECIFICATIONS.

(K) **Planning Characteristics.**

1. Major collector streets should be employed where traffic demands are high and right-of-way acquisition costs are not prohibited.

2. Detached sidewalk required.

3. Design element (trees, open space, etc.).

(L) **Type of Curb and Gutter.** Six (6) inch vertical.

(M) **Sidewalk Width.** Five feet (5') wide minimum. Detached from curb.

(N) **Street Widths.** Four (4) eleven-foot (11') travel lanes, two (2) two-foot (2') gutter pans.

6.14.00 ARTERIAL STREET

6.14.01 Minor Arterial

An arterial street is a general term denoting a roadway designated or operating with the following characteristics:

(A) **Posted Speed Limit.** Between 40 and 45 miles per hour. Posted or prima facie speeds for the various street classifications are normally five (5) to ten (10) miles per hour less than the design speed of that street.

(B) **Traffic Volumes.** Twelve thousand (12,000) vehicles per day expected minimum traffic volume when the land which the arterial serves is fully developed.

(C) **Access.** In accordance with Chapter 8 of these STANDARDS AND SPECIFICATIONS.

(D) **Continuity.** Several miles, generally connecting with inter-city routes.

(E) **Traffic Control.** Regulation of traffic accomplished by signs and channelization. Traffic signals will normally be located only at intersections with streets of high classification. Parking should be prohibited.

(F) **Function.** Arterial routes permit relatively unimpeded traffic movement and are intended for use on these routes where four (4) moving lanes and one (1) left-turn lane are required but where a major arterial cross-section would not be warranted. No parking is allowed.

(G) **Right-of-Way Width.** One hundred and thirty feet (130') minimum.

(H) **Number of Moving Lanes.** Four (4).

(I) **Planning Characteristics.** Arterials should be spaced from one-half (1/2) to one (1) mile apart and should, where possible, be continuous. Arterials should act as boundaries between neighborhood areas. Arterial cross-section should be employed where traffic demands are high and right-of-way acquisition costs are prohibitive. Detached sidewalk required. Separate major land uses.

(J) **Type of Curb and Gutter.** Six (6) inch vertical.

(K) **Sidewalk Width.** Eight-foot (8') minimum, detached from curb, or as required by the City Engineer.

(L) **Street Widths.** Four (4) eleven-foot (11') travel lanes, one (1) sixteen-foot (16') left-turn lane/striped or curbed median, and two (2) two-foot (2') gutter pans plus acceleration/deceleration lanes at intersections. Total street width shall be sixty-eight feet (68') flowline to flowline plus acceleration/deceleration lanes at intersections.

6.14.02 <u>Major Arterial (4-Lane)</u>

(A) **Posted Speed Limit.** Greater than or equal to 40 miles per hour. Posted or prima facie speeds for the various street classifications are normally five (5) to ten (10) miles per hour less than the design speed of that street.

(B) **Traffic Volumes.** Nineteen thousand (19,000) vehicles per day expected minimum traffic volume when the land which the arterial serves is fully developed.

(C) **Access.** In accordance with Chapter 8 of these STANDARDS AND SPECIFICATIONS.

(D) **Continuity.** Several miles, generally connecting with inter-city routes.

(E) **Traffic Control.** Movement of traffic will be controlled by signals and channelization. Parking shall be prohibited. Roadways should have a raised median strip between them.

(F) **Function.** Major arterial streets permit rapid and relatively unimpeded traffic movement throughout the country, connecting major lane use element, as well as communities with one another. No parking is allowed.

(G) **Right-of-Way Width.** One-hundred-thirty feet (130') minimum.

(H) **Number of Moving Lanes.** Four (4).

(I) **Planning Characteristics.** Major arterial streets should be spaced approximately one (1) mile apart and should traverse the entire city. Major arterial streets should not bisect neighborhoods but should act as boundaries between them.

(J) **Type of Curb and Gutter.** Six (6) inch vertical with two foot (2’) pan on outside of traveled way; six (6) inch vertical with one foot (1’) pan on medians.

(K) **Sidewalk Width.** Eight-foot (8') minimum, detached from curb, or as required by the City Engineer.

(L) **Street Widths.** Four (4) eleven-foot (11') travel lanes, from one (1) sixteen foot (16’) raised median, two (2) one-foot (1') median gutter pans, two (2) two-foot (2') gutter pans plus necessary left-turn and acceleration/deceleration lanes, and minimum four-foot (4') raised median at intersections.

6.14.03 <u>Major Arterial (6-Lane)</u>

(A) **Posted Speed Limit.** Greater than or equal to 50 miles per hour. Posted or prima facie speeds for the various street classifications are normally five (5) to ten (10) miles per hour less than the design speed of that street.

(B) **Traffic Volumes.** Thirty thousand (30,000) vehicles per day expected minimum traffic volume when the land which the arterial serves is fully developed.

(C) **Access.** In accordance with Chapter 8 of these STANDARDS AND SPECIFICATIONS.

(D) **Continuity.** Several miles, generally connecting with inter-city routes.

(E) **Traffic Control.** Movement of traffic will be controlled by signals and channelization. Parking shall be prohibited. Roadways should have a 4 foot (4') minimum raised median strip between them.

(F) **Function.** Major arterial streets permit rapid and relatively unimpeded traffic movement throughout the City, connecting major land use elements, as well as communities with one another. Parking is not allowed.

(G) **Right-of-Way Width.** One hundred fifty five foot (155') minimum.

(H) **Number of Moving Lanes.** Six (6).

(I) **Planning Characteristics.** Major arterial streets should be spaced approximately one (1) mile apart and should traverse the entire city. Major arterial streets should not bisect neighborhoods but should act as boundaries between them.

(J) **Type of Curb and Gutter.** Six (6) inch vertical with two foot (2') pan on outside of traveled way; six (6) inch vertical with one foot (1') pan on median.

(K) **Sidewalk Width.** Eight-foot (8') minimum, detached from curb, or as required by the City Engineer.

(L) **Street Widths.** Six (6) eleven-foot (11') travel lanes, one (1) sixteen foot (16') median, two (2) one-foot (1') median gutter pans, two (2) two-foot (2') gutter pans and necessary double left-turn lanes, acceleration/deceleration lanes, and four-foot (4') raised median at intersections.

6.15.00 DRAINAGE

The minor and major storm drainage systems shall be designed in accordance with the City of Westminster Storm Drainage Design and Technical Criteria Manual. Because safe and efficient movement of traffic is the primary function of roadways, the storm drainage function of roadways, (such as allowable gutter capacity and street overtopping), shall be designed to the limits set forth in the drainage criteria.

6.15.01 <u>Crosspans</u>

Crosspans shall be constructed in accordance with the detail drawing. Crosspans are not permitted across collector or arterial roadways, nor are they allowed on roadways with storm sewer systems. Double crosspans may be used parallel to collectors or arterial roadways to convey storm runoff across residential roadways. The use of double crosspans elsewhere, or the use of any crosspan on roadways where the vertical grade exceeds four-and-one-half percent (4.5%) will be considered only after all alternatives have been exhausted.

6.15.02 Inlets

Inlets shall be located to intercept the curb flow at the point curb flow capacity is exceeded by storm runoff. Refer to the City of Westminster's Storm Drainage Design and Technical Criteria Manual for curb capacity. Inlets shall also be installed to intercept cross-pavement flows at points of transition in superelevation. Due to the presence of handicap ramps, inlets shall not be allowed in the curb return but shall be located outside the tangent points of the curb returns. Gutter transition sections abutting inlets shall not be within the curb return.

6.15.03 Sidewalk Chases

Storm water from concentrated points of discharge shall not be allowed to flow over sidewalks but shall drain to the roadway or storm inlet by use of chase sections. Sidewalk chase sections shall not be located within a curb cut or driveway. Hydraulic design shall be in accordance with the Storm Drainage Design and Technical Criteria Manual. Sidewalk chase sections shall be constructed in accordance with the detail drawing.

6.15.04 Temporary Erosion Control

Temporary erosion control is required along and at the ends of all roadways that are not completed due to project phasing, subdivision boundaries, etc., in accordance with Chapter 2 of these STANDARDS AND SPECIFICATIONS.

6.16.00 HORIZONTAL ALIGNMENT

6.16.01 Horizontal Curves

The minimum horizontal curves for roadway alignment shall be in accordance with Table 6.16.01 below.

TABLE 6.16.01

Horizontal Curves

Design Speed (MPH)	Average Running Speed (MPH)	Maximum Degree of Curvature	Minimum Curve Radius*(Feet)
20	20	57.3	100
25	24	32.7	175
30	28	22.9	300
35	32	14.3	475
40	36	8.8	650
50**	44	6.0	955
55**	48	4.75	1200

* AASHTO Figure 111-18 - for low speed urban street - normal crown.
** Requires Superelevation - 0.04 ft/ft maximum.

6.16.02 Curb Return Radius

Minimum return radius shall be as shown in Table 6.16.02 below.

TABLE 6.16.02
Curb Return Radii
(Measured Along Flowline)

	Intersecting Streets		
Through Street	Arterial	Collector	Local Service
Arterial	50 Feet	30 Feet	25 Feet
Collector	30 Feet	25 Feet	20 Feet
Local Service	25 Feet	20 Feet	15 Feet

6.16.03 Design Speed

Horizontal alignment design speed shall be consistent with the requirement for vertical alignment design speed. If no superelevation is required and normal crown section exists, the horizontal curve data as shown in Table 6.16.01 shall be used.

6.16.04 Spiral Curves

Spiral curves shall be used only on arterial roadways within the City of Westminster and only upon written approval of the City Engineer.

6.16.05 Small Deflection Angles

For small deflection angles, curves should be sufficiently long to avoid the appearance of a kink. Curves should be at least five hundred (500) feet long for a central angle of five degrees (5°), and the minimum length should be increased one hundred feet (100') for each one-degree (1°) decrease in the central angle. Horizontal curves should not be used when the central angle is fifty-nine minutes (59') or less. This criteria applies to arterial roadway design only.

6.16.06 Compound Curves

A compound curve on arterials should be avoided, particularly where a simple curve can be obtained at small extra cost. Where topography makes their use necessary, the radius of the flatter curve should not be more than fifty percent (50%) greater than the radius of the sharper curve. When this is not feasible, an intermediate curve or spiral should be used to provide the necessary transitions. Spiral curves are only to be used upon written approval of the City Engineer.

6.16.07 Reversing Curves

True reversing curves should not be used. In cases of reversing curves, a sufficient tangent should be maintained to avoid overlapping of the required superelevation runoff and tangent runout. The following is the minimum tangent lengths that shall be used for each roadway classification:

(A) Local -- not applicable.

(B) Collector -- Fifty feet (50') minimum.

(C) Arterial -- One hundred feet (100') minimum.

6.16.08 Broken-Back Curves

A broken-back curve consists of two (2) curves in the same direction joined by a short tangent, of length less than one thousand five hundred feet (1500'). Broken-back curves are undesirable. If the length of intervening tangent is less than one thousand five hundred feet (1500'), a simple curve, a compound curve, or spiral transitions should be used to provide some degree of continuous superelevation. Spiral curves are only to be used upon written approval of the City Engineer.

6.16.09 Alignment at Bridges

Ending a curve on a bridge is undesirable and adds to the complication of design and construction. Likewise, curves beginning or ending near a bridge should be so placed that no part of the spiral or superelevation transitions extends onto the bridge. Compound curves on a bridge are equally undesirable. If curvature is unavoidable, every effort should be made to keep the bridge within the limits of the simple curve.

6.16.10 Coordination With Vertical Alignment

To avoid the possibility of introducing serious traffic hazards, coordination is required between horizontal and vertical alignment. Particular care must be exercised to maintain proper sight distance at all times. Sharp horizontal curves introduced at or near the top of pronounced crest or bottom of sag vertical curves should be avoided. Vertical curvature superimposed upon horizontal curves, or vice versa, generally results in a more pleasing facility.

6.17.00 VERTICAL ALIGNMENT

Vertical Alignment Control Table:

Design Controls for vertical alignment are shown on Table 6.17.00.

TABLE 6.17.00
Vertical Alignment Controls

Description	Design Speed*	Maximum Grade**	K Value Crest	Ranges Sag	Minimum VCL Crest	Sag
Local	35	8	40-50	30-50	50	50
Minor Collector	40	7	60-80	60-70	50	50
Major Collector	50	7	110-160	90-110	100	80
Minor Arterial	50	6	110-160	90-110	100	80
Major Arterial***	55	6	150-220	100-130	110	90

* The design speed is a minimum of 5 miles per hour over the posted speed for each classification.

** The maximum grades indicated should only be used in extreme topographic conditions. The designer should strive to minimize the use of these grades for considerable lengths and on north-facing slopes.

*** K values exceeding 125 on curbed streets should be checked for drainage. Multiple inlets may be required within long sag on vertical curves, and where the longitudinal slope is less than 0.4 percent.

6.17.01 Permissible Roadway Grade

The minimum allowable grade for roadways is one-half percent (0.5%). The minimum allowable grade for bubbles and cul-de-sacs within the bulb is one percent (1%). The maximum allowable grade for any roadway is shown in Table 6.17.00 above.

6.17.02 Permissible Intersection Grades (Public Rights-of-Way)

The maximum permissible grade at intersections shall be as shown in the detail drawing. These grades are maximum instantaneous flowline grades for the stated distances (each side of the street) for the minor (intersecting) street.

The intersection grade of the major (through) street at the intersection may be dictated by design considerations for the street. However, if the major street intersection grade exceeds

three percent (3%), the type of access and access control will be as directed by the City Engineer.

All private commercial driveways with curb return radii shall follow the standards set forth for a local street. The length of the maximum grade for the commercial driveway shall be a minimum of fifty feet (50') measured from the flowline intersection of the public roadway.

6.17.03 <u>Changing Grades</u>

The use of grade breaks in lieu of vertical curves is discouraged. However, if a grade break is necessary and the algebraic difference in grade does not exceed eight-tenths of a percent (0.008 ft./ft.) along the roadway, the grade break will be permitted. The maximum grade break allowed at the point of tangency at a curb return for local and collector roads shall be two percent (2%) and for arterial roadways a maximum of one percent (1%).

6.17.04 <u>Vertical Curves</u>

When the algebraic difference in grade (A) is at, or exceeds, eight-tenths of a percent, a vertical curve is to be used. Design criteria for vertical curves is found in Table 6.17.00 of this chapter. The minimum gradients into and out of a sag (sump) vertical curve is five-tenths of a percent (0.005 ft./ft.). Minimum length of a vertical curve is shown in Table 6.17.00 of this chapter. All vertical curves shall be labeled in the profile with length of curve (L), K=L/A values, VPC, VPT, VPI, and stationing and elevation of these components. In addition, the low point or high point of the vertical curve shall be shown.

6.17.05 <u>Intersections</u>

In addition, the following criteria shall apply at intersections.

(A) The grade of the "through" street shall take precedence at intersections. At the intersections of roadways with the same classification, the more important roadway, as determined by the City Engineer, shall have this precedence. The design should warp side streets to match through streets with as short a transition as possible.

(B) The key criteria for determining the elevation of the curb return on the side street and the amount of warp needed on a side street transitioning to a through street are:

1. Permissible grade in the stop/start lane. See Section 6.17.02 of these STANDARDS AND SPECIFICATIONS.

2. Pavement cross slope at the PCR's on the side street and permissible warp in pavement cross slope (see Section 6.19.01(B)).

3. Normal vertical curve criteria.

4. Vertical controls within the curb return itself.

(C) The elevation at the PCR of the curb return on the through street is always set by the grade of the through street in conjunction with pavement cross slope.

(D) Carrying the crown at a side street into the through street is permitted only when drainage considerations warrant such a design.

(E) A more detailed review shall be performed for arterial-arterial intersections to maximize driveability. A few arterial intersections will have a uniform two percent (2%) cross-slope, the majority of them having one or more sides warped.

(F) Whenever possible, intersections shall be made at right angles or radial to a curve. No intersecting angle of less than seventy-five degrees (75°) will be allowed.

6.17.06 Curb Returns

Minimum fall around curb returns for flow along the curb line shall be as follows:

Table 6.17.06
Curb Returns

Radius	Minimum Fall
15 Feet	0.3 Feet
20 Feet	0.3 Feet
25 Feet	0.4 Feet
30 Feet	0.4 Feet
50 Feet	0.5 Feet
All Others	1.2 Percent Around the Return

6.17.07 Curb Return Profiles

Curb return profiles are required for radii equal to or greater than twenty five (25') within the public right-of-way. A mid-point elevation along the arc length of the curb return shall be shown in plan view for radii equal to or greater than twenty-five feet (25'). Curb return design shall be set in accordance with the following design procedure. General standards for flowline control and profiles with the curb returns shall be as follows:

(A) The point of tangency at each curb return shall be determined by the projected tangent grade beginning at the point of intersection (PI) of the flowlines.

(B) The arc length and external distances of the curb return shall be computed and indicated on the drawing.

(C) Show the projected flowline (or top of curb) grade for each roadway beyond the PCR.

(D) Design the flowline of the curb return such that a maximum cross slope between the mid-point of the curve and the PICR (external distance) does not exceed five percent (5%). Grade breaks at the PCRs shall not exceed two percent (2%) for local and collector streets and one percent (1%) for arterials. The flowline design of the curb return shall be accomplished within the return without affecting street grades beyond the PCR. Maximum vertical curves will equal the arc length of the curb return. The elevation and location of the high or low point within the return, if applicable, is to be called out in the profile.

(E) Scale for the curb return profile to be one inch equals one foot (1"=1') vertically.

6.17.08 Connection With Existing Roadways

(A) Connection with existing roadways shall be smooth transitions conforming to normal vertical curve criteria if the algebraic difference in grade between the existing and proposed grade exceeds eight-tenths (0.008 ft./ft.) of a percent. When a vertical curve is used to make this transition, it shall be fully accomplished prior to the connection with the existing improvements and shall also comply with the grade requirements at intersection approaches.

(B) Existing grade shall be shown for at least three hundred feet (300') with field verified as-builts showing stations and elevations at twenty-five-foot (25') intervals. In the case of connection with an existing intersection, these as-builts are to be shown within a three-hundred-foot (300') radius of the intersection. This information will be included in the plan and profile that shows that proposed roadway. Limits and characteristics of the proposed improvement are the primary concern in the plan view. Such characteristics include horizontal alignment, off-site intersections, limits of the improvement, etc.

(C) Previously approved designs for the proposed improvement are not an acceptable means of establishing existing grades. However, they are to be referenced on the construction plan where they occur.

(D) The basis of the as-built elevations shall be the design elevations (both flowline or both top of curbs, etc.) when possible.

6.18.00 SIGHT DISTANCES

6.18.01 General

The major considerations in alignment design are safety, grade, profile, road area, design speed, sight distance, topography, drainage, and performance of heavy-duty vehicles. The road alignment should provide for safe and continuous operation at a uniform design speed. New road layout shall bear a logical relationship to existing or platted roads in adjacent properties. Design for site distances shall be in accordance with the following:

Adequate intersection design necessitates the provision of safe ingress and egress from one street or driveway to the other, based in part on the ability of a driver to see oncoming vehicles or pedestrians. The following guidelines shall be used in the design of intersections, private driveways and public streets which intersect other traffic carrying facilities.

6.18.02 <u>Sight Distance Triangle</u>

At the intersection of two public streets or a private driveway and a public street, sight distance shall be evaluated across a "sight distance triangle" where obstructions are restricted according to the following criteria. Within the area of the triangle there must be no wall, fence, sign, foliage, berming or other structure which will obscure the driver's view of traffic approaching that intersection. The structures or berms within the sight distance triangle can extend no higher than 24 inches above the curb elevation.. Exceptions to this requirement exist for public facilities such as fire hydrants, utility poles and traffic control devices. These facilities must be located to minimize visual obstruction.

The evaluation of sight distance shall be made on two different types of sight distance areas. The first is shown in Figure 6.18.01 for the intersection of two public streets. The sight distance triangle in this case is formed by the intersection of two lines plotted along the curb line of the intersecting streets using the specified lengths. The diagonal connects the other ends of those lines. Where one or the other of the intersecting streets/driveways has no curb, the lines are plotted along the edge of the traveled way.

The second sight distance triangle is shown in Figure 6.18.02, and is formed by lines plotted along the flowlines or edge of traveled way of both streets and the diagonal lines d_1 and d_2 as shown. Distance d_1 is measured to vehicles approaching from the left and d_2 is measured to those approaching from the right. The sight lines (d_1 and d_2) have their origin at the stopped driver's eye, located ten feet (10') behind the flowline of the street being entered.

Tables 6.18.01 through 6.18.04 show recommended sight distances d_1, and d_2 for passenger vehicles and semi-tractor trailer trucks for several different vehicle operating speeds and roadway configurations. The tables were developed according to the following general criteria:

1. Vehicles turning left or right can accelerate to the operating speed of the intersecting street without causing approaching vehicles to reduce speed by more than ten miles per hour.

2. Vehicles turning left can clear the near half of the street without conflicting with vehicles approaching from the left.

3. The distance requirements are based on the driver's eye being 3.5 feet above the roadway and an object height of 4.25 feet. For semi-tractor trailers, a six foot driver's eye height and a 4.25 feet object height are assumed.

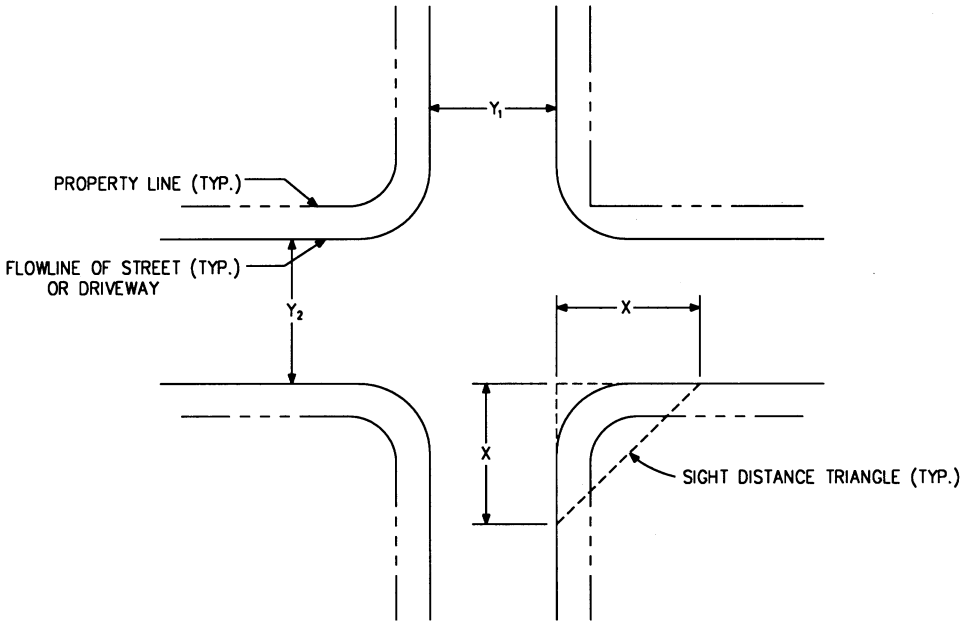
4. The operating speed on each approach is assumed to be (in the order of desirability):

    A. The 85th percentile speed;

    B. The speed limit, if based on a traffic engineering study;

    C. The design speed in the case of a new facility.

SIGHT DISTANCE TIANGLES



NOTE: IF $Y_1 \neq Y_2$ USE THE LARGER OF THE TWO TO DETERMINE THE "LEG LENGTH" OF THE SIGHT DISTANCE TRIANGLE

FLOWLINE TO FLOWLINE (Y)	LEG LENGTH (X)
≤ 36 FT.	35 FT.
≤ 44 FT.	45 FT.
>= 45 FT.	55 FT.

FIGURE 6.18.01

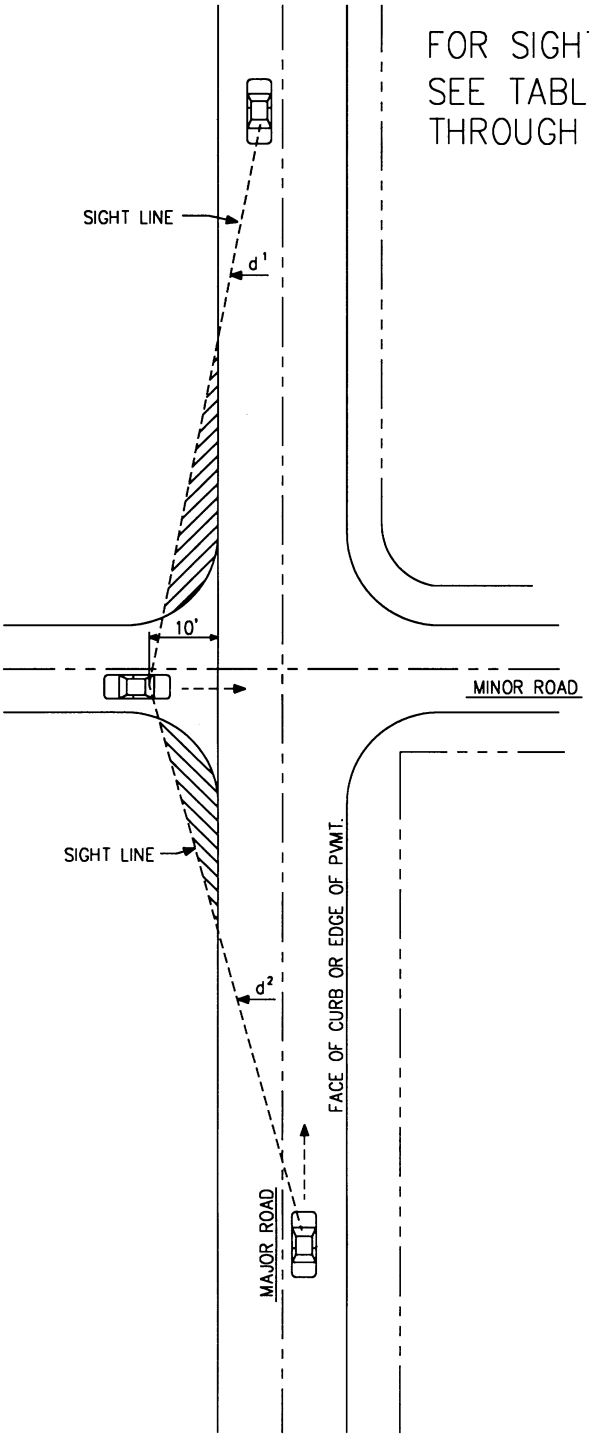


FIGURE 6.18.02

When the criteria for sight distance cannot be met, the City may prohibit certain turns by exiting vehicles to provide safe operating conditions. These standards apply to accesses on State Highways and City streets.

TABLE 6.18.01

Sight Distance (feet) for Passenger Cars Exiting from Private Accesses or Public Streets onto Two-Lane Roads

Speed (mph)	Safe Sight Distance - Left [1] d_2	Safe Sight Distance - Right [1] d_2
20	150	130
25	240	200
30	350	260
35	430	350
40	530	440
45	610	570
50	740	700
55	830	860
60	950	1,050

[1] Measured from the driver's eye ten feet back of the flowline or pavement edge.

TABLE 6.18.02

Sight Distance (feet) for Passenger Cars Exiting from Private Accesses or Public Streets onto Four and Six-Lane Roads

Speed (mph)	Safe Sight Distance - Left [1] d_2	Safe Sight Distance - Right [2] d_2
20	130	130
25	180	200
30	220	260
35	300	350
40	380	440
45	500	570
50	620	700
55	760	860
60	950	1,050

[1] Measured from the driver's eye ten feet back of the flowline or pavement edge to a vehicle in the outside lane.

[2] Measured from the driver's eye ten feet back of the flowline or pavement edge to a vehicle approaching in the median lane.

TABLE 6.18.03

Sight Distance (feet) for Semi-Trailers Exiting from Private Accesses or Public Streets onto Two-Lane Roads

Speed (mph)	Safe Sight Distance - Left [1] d_2	Safe Sight Distance - Right [2] d_2
20	300	200
25	400	320
30	680	400
35	850	640
40	1,160	850
45	1,600	1,160
50	2,000	1,600
55	2,500	2,000
60	950	2,500

[1] Measured from the driver's eye ten feet back of the flowline or pavement edge.

[2] Measured from the driver's eye ten feet back of the flowline or pavement edge to a vehicle approaching in the median lane.

TABLE 6.18.04

Sight Distance (feet) for Semi-Trailers Exiting from Private Accesses or Public Streets onto Four and Six-Lane Roads

Speed (mph)	Safe Sight Distance - Left [1] d_2	Safe Sight Distance - Right [2] d_2
20	200	200
25	320	320
30	400	400
35	640	640
40	850	850
45	1,160	1,160
50	1,600	1,600
55	2,000	2,000
60	2,500	2,500

[1] Measured from the driver's eye ten feet back of the flowline or pavement edge.

[2] Measured from the driver's eye ten feet back of the flowline or pavement edge to a vehicle approaching in the median lane.

The sight distance shown in Tables 6.18.05 and 6.18.06 are required for vehicles turning left form a public street to allow them a clear view of oncoming vehicles and complete the maneuver safely.

TABLE 6.18.05

Sight distance (ft.) for Passenger Cars Entering Private Accesses or Public Streets by Left Turns from a Public Street

	Safe Sight Distance in Feet [1]		
Speed (mph)	2-Lane	4-Lane	6-Lane
20	150	160	170
25	190	200	220
30	230	250	270
35	300	320	340
40	370	390	420
45	450	470	500
50	520	550	580
55	600	630	670
60	700	740	780

[1] Measured from the point where a left turning vehicle stops to a vehicle approaching in the outside lane.

TABLE 6.18.06

Sight distance (ft.) for Semi-Trailers Entering Private Accesses or Public Streets by Left Turns from a Public Street

	Safe Sight Distance in Feet [1]		
Speed (mph)	2-Lane	4-Lane	6-Lane
20	260	280	300
25	330	360	380
30	400	440	480
35	480	540	580
40	570	620	670
45	680	730	800
50	810	880	950
55	910	990	1,060
60	1,000	1,100	1,200

[1] Measured from the point where a left turning vehicle stops to a vehicle approaching in the outside lane.

The sight distances in Tables 6.18.01 and 6.18.04 apply when highway grades are zero to 3.0% (either up or down). When grades are steeper than 3.0%, adjustments must be made to compensate for the different distances required to reach the speed of highway traffic. Adjustment factors are provided in Table 6.18.07.

TABLE 6.18.07

Factors for the Effect of Grade on Sight Distance

Grade	Downgrade Factor [1]	Upgrade Factor [2]
0 - 3#	1.0	1.0
3.1 - 5%	0.6	1.4
5.1 - 8%	0.5	1.7

[1] When the highway in the section to be used for acceleration after leaving the access descends, sight distance in the direction of approaching descending highway traffic should be reduced by these factors.

[2] When the highway in the section to be used for acceleration after leaving the access ascends, then sight distance in the direction of approaching ascending should be increased by these factors.

6.19.00 ROADWAY CROWN

6.19.01 Cross Slope

Except at intersections or where superelevation is required, roadways shall be level from top of curb to top of curb (or flowline to flowline) and shall have a minimum two percent (2%) crown. Within one-hundred-fifty feet (150') of an intersection, the maximum elevation difference between flowlines shall be dictated by the allowable intersection grade and the actual distance between flowlines.

(A) Parabolic or curved crowns are not allowed. In no case shall the pavement cross slope at warped intersections exceed the grade of the through street.

(B) The rate of change in pavement cross slope when warping side streets at intersections shall not exceed one percent (1%) every twenty-five feet (25') horizontally on a local roadway, one percent (1%) every thirty-seven-and-one-half feet (37.5') horizontally on a collector roadway, or one percent (1%) every fifty-six-and-one-half feet (56.5') horizontally on arterial roadway.

(C) In the case of conflict caused by requirements of the Storm Drainage Design and Technical Criteria Manual, the drainage requirements shall govern.

6.19.02 Superelevation

Superelevation is required for curves on all arterial roadways and selected collector roadways. Horizontal curve radius on superelevation shall be in accordance with the recommendations of the AASHTO "A Policy on Geometric Design of Highways and Streets", latest edition (Green Book).

Superelevation shall not be used on local or other roadway classifications with a design speed of 40 miles per hour or less. The following procedure is an outline for the correct application of superelevation on roadways within the City of Westminster.

(A) Definitions Regarding Superelevation:

Superelevation Runoff. That length of roadway needed to accomplish the change in cross slope from a section with the adverse crown removed (flat) to the fully superelevated section, or vice versa.

Transition Points. Beginning or ending of tangent run-out, superelevation runoff, or full superelevation.

Tangent Run-Out. That length of roadway needed to accomplish the change in cross slope from a normal (2 percent) crown section to a section with the adverse crown removed (flat), or vice versa.

(B) General:

One of the most important factors to consider in highway safety is the centrifugal force generated when a vehicle traverses a curve. Centrifugal force increases as the velocity of the vehicle and/or the degree of curvature increases. In order to overcome the effects of centrifugal force, curves should be superelevated. It is impossible to balance centrifugal force by superelevation alone because for any given curve radius a certain superelevation rate is exactly correct for only one driving speed. At all other speeds there will be a side thrust either outward or inward, relative to the curve center, which must be offset by side friction.

(C) Standards for Superelevation:

AASHTO's Green Book, Table 111-8 on superelevation give the required rates of superelevation for the various degree of curvature. Maximum superelevation rate of 0.04 foot per foot are commonly used on major streets.

(D) Urban Street Conditions:

Every effort should be made to maintain standard rates of superelevation. However, in urban areas street intersections, established street grades, curbs, and drainage conditions may require a reduction in the rate of superelevation or different rates for each half of the road bed. In warping areas for drainage, adverse superelevations should be avoided.

6.20.00 SIDEWALKS, CURB AND GUTTERS, RAMPS, AND DRIVEWAYS

(A) Roadway typical sections shall be as specified by these STANDARDS AND SPECIFICATIONS.

(B) Sidewalks or bicycle paths shall be constructed on both sides of all roadways unless specifically deleted by action of City of Westminster Planning Department.

(C) All sidewalks used in conjunction with vertical curb and gutter shall have a minimum width of four feet (4').

(D) Combination curb, gutter, and walk is approved for use on local roadways and minor rural collectors only. Vertical curb, gutter, and detached walk shall be used on all other roadways.

(E) State law requires that handicap ramps be installed at all intersections and at certain mid-block locations for all new construction of curb and sidewalk [CRS 43-2-107(2)]. Handicap ramps shall be constructed in accordance with the detail drawings in these STANDARDS AND SPECIFICATIONS. Handicap ramps may be shown at all curb returns or called out by a general note on the development plans, but must be shown (located) on all "T" intersections. Whenever referencing a handicap ramp, call out the specific detail drawing to construct that ramp. Handicap ramps to be poured monolithic with the abutting curb and gutter. The ramp portion shall be constructed with “Truncated Domes/Detectable Warning Devices” colored “Pavestone River Red” in accordance with the detail drawings.

(F) Drainage structures shall not be placed in line with handicap ramps. Location of handicap ramps shall take precedence over location of the drainage structure.

(G) Curb cuts should not be used for commercial/industrial or high volume residential driveways. In general, when the number of parking spaces services by the driveway exceeds ten (10), radius returns should be used.

(H) Where curb cuts are allowed based on traffic considerations, concentrated storm water runoff must not be discharged across the sidewalk. These flows must be directed to a sidewalk chase section. If this is not possible due to grading restraints, radius returns and a crosspan shall be used.

(I) Curb cuts and driveways shall be constructed in accordance with the detail drawings in these STANDARDS AND SPECIFICATIONS.

6.21.00 CUL-DE-SACS

The following criteria shall be used for cul-de-sac horizontal geometry.

(A) The minimum property line radius shall be fifty feet (50').

(B) The minimum flowline radius shall be forty feet (40'). See the detail drawing in this section.

(C) The maximum length of the cul-de-sac as measured along and between the radius point and the right-of-way line on the abutting street shall be five hundred feet (500') or a maximum of fifteen (15) residential dwelling units, whichever is greater.

(D) Vertical alignment shall be in accordance with Section 6.17.00 of these STANDARDS AND SPECIFICATIONS.

6.22.00 DECELERATION LANES

The design of the arterial street system depends upon the proper control of access to developments. The location and design of access points must minimize traffic hazards and interference to through traffic movements. To ensure proper control, the following standards for deceleration lanes have been established. The need for deceleration lanes is established by the approved traffic study for the final plat or final development plan.

(A) Requests for exemption from the requirements for a deceleration lane shall be based upon a traffic engineering study that presents trip-generation data for the proposed development in terms of impacts upon through traffic flows. Such requests shall be reviewed by the City Traffic Engineer and may be approved, except that such an approval cannot be granted if through traffic would be impeded more than three percent (3%) of the total time, more than five percent (5%) of the time during peak traffic flow periods, or if other unique circumstances warrant special design considerations.

(B) Deceleration lanes may be required along segments of collector streets if the proposed development constitutes a potential for creating a traffic hazard or unnecessarily impedes through traffic movements.

(C) Deceleration lanes shall have a minimum paved width of eleven feet (11') unless otherwise approved at a lesser width by the City Engineer.

(D) The vehicle storage length of the deceleration lane shall be based upon the peak hour turning volume for the development as follows:

TABLE 6.22.01
Deceleration Lanes

Peak Hour Volume	Minimum Length
35-50	40 Feet
51-60	50 Feet
61-100	100 Feet
101-200	175 Feet
201-300	250 Feet

Deviations from this criteria shall be in accordance with AASHTO "A Policy on Geometric Design of Highways and Streets", latest edition (Green Book).

(E) The lead-in taper length plus additional deceleration length for the deceleration lane shall be based upon the posted speed limit along the street.

TABLE 6.22.02
Deceleration Tapers

Speed Limit	Deceleration Length	Taper Ratio*
30 MPH & Under	160 Feet	8:1
35 MPH	250 Feet	12:1
40 MPH	370 Feet	12:1
45 MPH	425 Feet	15:1
50 MPH	500 Feet	15:1

* Taper length equals taper ratio times lane width.

(F) Deceleration lanes shall be provided for all exclusive right-turn access points (i.e., right-in/right-out driveways).

(G) The deceleration lane and the associated signage and pavement marking shall be installed as per the requirements established by the City Traffic Engineer prior to the issuance of any Certificate of Occupancy within the development.

6.23.00 ACCELERATION LANES

At intersections, it is desirable to provide acceleration lanes for vehicles turning right onto the arterial from a cross street. The design elements of these acceleration lanes shall be in accordance with Tables 505.7B and 505.7C of the Colorado Department of Transportation Roadway Design Manual.

6.24.00 BUS PULL-OUT LANES

If recommended by the Regional Transportation District or required by the City, bus pull-out lanes shall be designed and constructed by the adjacent subdivider.

(A) The design of the pull-out lanes shall be governed by dimensions shown in Table 6.24.01 and the detail drawing in this section; and shall be reviewed and approved according to procedures set forth in these design standards.

TABLE 6.24.01
Bus Pull-Out Lanes

Speed Limit	Lead-In Length	Lead-Out Length
35 MPH & Under	60 Feet	60 Feet
40 MPH	100 Feet	70 Feet
45 MPH	150 Feet	80 Feet
50 MPH	200 Feet	90 Feet
55 MPH	250 Feet	100 Feet

(B) The pavement design report shall consider the requirements of the pull-out lane separately from the adjacent roadway.

(C) Bus pull-outs shall be constructed with no less than fifty feet (50') between an intersection curb return curve (PC) and the beginning of the lead-in taper.

6.25.00 OFF-SITE DESIGN

(A) The design grade, and existing ground at that design grade, of all roadways that dead end due to project phasing, subdivision boundaries, etc., shall be continued in the same plan and profile as the proposed design for at least three hundred feet (300') or to its intersection with an arterial roadway.

(B) If the off-site roadway adjacent to the proposed development is not fully improved, the developer is responsible for the design and construction of a transition for the safe conveyance of traffic from his improved section to the existing roadway. The following formula shall be applied to the taper of lane change necessary for this transition:

$$L = WS^2/60$$

Where:

L = Length of Transition in Feed
W = Width of Offset in Feet
S = Speed Limit or 85th Percentile Speed

(C) The City of Westminster Engineering Division should be contacted to establish unusual transition criteria. This contact is the responsibility of the applicant.

6.26.00 BARRICADES

Whenever roadways terminate due to project phasing, subdivision boundaries, etc., barricades are required. Design and construction shall comply with the requirements of the Manual of Uniform Traffic Control Devices, most recent edition. Details shall be shown on the construction drawings, and installation shall be provided by the developer.

6.30.00 PAVEMENT DESIGN AND TECHNICAL CRITERIA

6.31.00 GENERAL

This section provides the basic criteria and design procedures for roadway pavements. Recommended design methodologies for asphalt and Portland cement concrete are addressed and essentially follow the Colorado Department of Transportation methodology. Some standardization of criteria has been made in design procedures.

For all City land development approvals that involve a Public Improvements Agreement for roadway construction, the applicant shall provide a subgrade investigation and pavement design report that recommends typical pavement structural section based on the known site soil conditions and the valid traffic study. This pavement design serves as a justification of the roadway improvements agreement in addition to determining roadway structural requirements.

6.32.00 SUBGRADE INVESTIGATION

All subgrade investigation shall be in accordance with the procedures outlined in the "Manual" With the more specific criteria as follows:

*The field investigation shall consist of borings or other suitable methods of sampling subgrade soils to a depth of at least three feet (3') below proposed subgrade elevation at spacings of not more than two hundred fifty feet (250') unless otherwise accepted by the City Engineer. Samples shall be taken after grading is completed and the subgrade is rough cut.

*The treatment of expansive soils shall be in accordance with Section 2.3 of the "Manual" unless approved otherwise, in writing, by the City Engineer.

*The "Subgrade Resilient Modulus"(Mg) shall be correlated the Resistance Value (R-value) using the formulas in the "Manual", If the Plasticity Index (PI) of the subgrade is more than 15 or the R-value of the soil is less than 10, then the subgrade shall be stabilized with one of the methods outlined in the "Manual".

6.33.00 PAVEMENT DESIGN CRITERIA

6.33.01 General

This section provides the parametric input data to be used for the design of pavements of various roadway classifications.

6.33.02 Equivalent (18 Kip) Single Axle Load Applications (ESAL)

The pavement design procedure in this section provides for a 20-year service life of pavement, given that normal maintenance is provided to keep roadway surface in an acceptable condition. ESAL and Design Traffic Number (DTN) are considered equivalent units based on 20-year design criteria and an 18 Kip axle loading. All data and design nomographs in this chapter use ESAL units for pavement loading repetitions. Minimum ESAL criteria for each City of Westminster roadway classification are given in Table 6.33.02 and are to be used when a traffic study indicates lesser ESAL values.

TABLE 6.33.02
Minimum Equivalent (18 Kip) Single Axle Load Applications (ESAL)

Classification	Class Modifier	ESAL Values
Cul-de-Sac	Serving < 10 D.U.	14,600
Local	Serving < 80 D.U.	36,000
Minor Collector	Residential	219,000
	Commercial	365,000

Major Collector`	All	730,000
Minor Arterial	All	1,460,000
Major Arterial	All	1,460,000

(1) ESAL for major arterial roadways shall be set on a case-by-case basis; 1,460,000 is the recommended minimum for planning purposes.

6.33.03 <u>Design Serviceability Loss (APSI)</u>

The following criteria shall be used for all City of Westminster roadways to be dedicated for public use: ASI is based on an initial serviceability index of 4.5 and is the value to use in the CDOT procedure.

TABLE 6.33.03
Serviceability Index and Loss

Roadway Classification	SI	ASI
Arterials (Minor, Major)	2.5	2.0
Collectors:		
Major	2.5	2.0
Minor Commercial	2.5	2.0
Minor Residential	2.5	2.0
Local and Private Parking Lots	2.0	2.5

6.33.04 Reliability

Reliability is the probability that the pavement system will perform its intended function over its design life (or time) and under the conditions (or environment) encountered during operation.

TABLE 6.33.04
Reliability (Risk)

Functional Classification	Reliability
Principal Arterials	95
Minor Arterials	95
Collectors	90
Local	80

6.33.05 Minimum Pavement Section

This paragraph provides the minimum acceptable pavement sections for public roadways in the City of Westminster. These pavement thicknesses may be used for preliminary planning purposes. Final pavement designs must be based on actual subgrade support test results. Table 6.33.04 lists these minimum thicknesses for each roadway classification.

TABLE 6.33.05
Minimum Pavement Sections

Classification	Composite Asphalt Inches	Section Treated Subgrade	Full Depth Asphalt (Inches)	Portland Cement (2) Concrete (Inches)
Cul-de-Sac (1)	--	--	6.0	6.0
Local	4	8	5.0	5.0
Minor Collector				
(A) Residential `	4	8	7.0	5.0
(B) Commercial	4	8	7.0	5.5
Major Collector	4	8	7.0	5.5
Minor Collector	5	8	7.0	6.0
Major Arterial	6	8	9.0	6.0

(1) All cul-de-sacs shall be the minimum full depth shown or the full depth determined by the subgrade support tests, whichever is greater.

(2) Concrete streets are only allowed with specific written approval of the City Engineer.

(3) "Full Depth Asphalt" is required on all "Public Streets". Composite sections will only be allowed
When specifically approved by the City Engineer.

6.33.06 Flexible Pavement Strength Coefficients

Table 6.33.06 contains the standard design coefficients for various pavement materials. Non-standard design coefficients may be used only if approved in advance by the City Engineer. In addition, design values shall be verified by predesign mix test data and supported by daily construction tests or redesign values shall be required; i.e., such as add one-half inch (1/2") to one inch (1") to the in-place surface course of final asphalt concrete.

TABLE 6.33.06
Strength Coefficients

Pavement Structure Component*	Structural Layer Coefficients	(Limiting Test Criteria)
Conventional Materials:		
Hot Bituminous Pavement	0.44	
Exist Bituminous Pavement	0.30	(9-15 yr)
	0.24	(> 15 yr)
Aggregate Base Course	0.14	(R≥83)
Aggregate Base Course	0.12	(77≤R-value<83)
Aggregate Base Course	0.11	(69≤R-value<77)
Aggregate Base Course	0.10	(R-value <69
Treated Materials:		
Cement-Treated Aggregate Base	Refer to the “Manual”	
Lime-Treated Subgrade	Refer to the “Manual”	

*The combination or one or more of the following courses placed on a subgrade to support the traffic loading and distribute it to the road bed.

(A) Subbase. The layer or layers of specified or selected material of designed thickness placed on a subgrade to support a base course, surface course, or both.

(B) Base Course. The layer or layers of specified or selected material of designed thickness placed on a subbase or a subgrade to support a surface course.

(C) Surface Course. One or more layers of a pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer is sometimes called "wearing course."

6.34.00 PAVEMENT DESIGN PROCEDURE

6.34.01 Flexible Pavements

(A) The following procedure should be used in determining the structural number (SN) of the pavement being designed.

1. Determine roadway classification and corresponding ESAL (Traffic Study or Table 6.33.02 whichever is greater).

2. Determine the serviceability loss (ASI) of the roadway classification (Table 6.33.03).

3. M_R value of subgrade as determined by soils report from laboratory and/or correlation equation below:

   Convert Hveem "R" to Soil Support

   $S_1 = [(\text{"R"} - 5)/11.29] + 3$

   To Convert S_1 to M_R

   $M_R = 10^{[S_1 + 18.72]/6.24}$

4. Structural Layer Coefficients (Table 6.33.06)

5. Overall deviation, So, which is 0.44 for flexible pavement.

6. Reliability, R, (see Table 6.33.04)

7. Use nomograph (Table 6.34.01) or use the AASHTO pavement design software,DARWin™ to obtain the Structural Number (SN).

8. Once the structural number (SN) has been determined, the design thicknesses of the pavement structure can be determined by the general equation:

$SN = a_1 D_1 + a_2 D_2 + a_3 D_3 + \ldots$

Where:

a_1 = Hot Bituminous Pavement (HBP) strength coefficients

D_1 - Thickness of Hot Bituminous Pavement (HBP) (inches)

D_2, D_3, D_n - Thickness of Additional Pavement Component Sections (inches)

a_2, a_3, a_n - Strength coefficient for the corresponding pavement structure *

- The Strength coefficients for various components of the pavement structure are given in Table 6.33.06. The component thickness selected must meet two conditions:

a. Total HBP thickness selected cannot be less than the minimum specified in Table 6.33.05 for the roadway classification

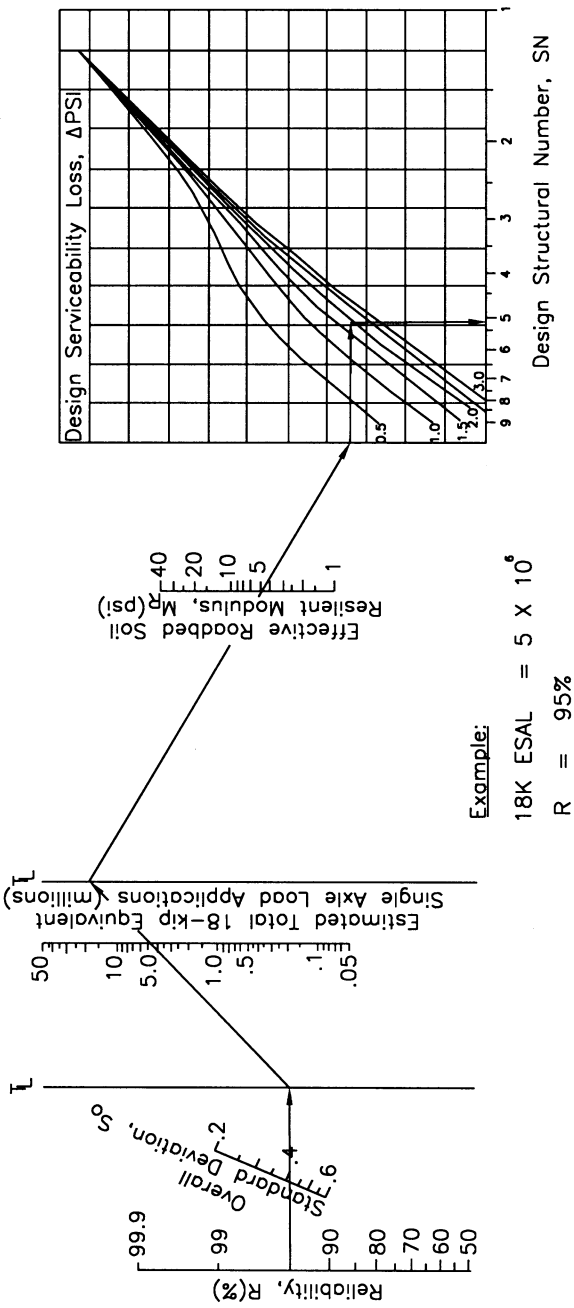
b. The base course thickness cannot exceed 2.5 times the HBP thickness selected. If a base
course section is allowed, in writing, by the City Engineer.

TABLE 6.34.01

Flexible Pavement Design

NOMOGRAPH SOLVES:

$$\log_{10} 18^{K}ESAL = Z_R * S_o + 9.36 * \log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2 - 1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32 * \log_{10} M_R - 8.07$$



Example:

18K ESAL = 5×10^6

R = 95%

S_o = 0.44

M = 5000 psi

ΔPSI = 2.0

Solution: SN = 5.1

6.34.02 <u>Rigid Pavement</u>

If rigid pavement is allowed by the City Engineer, the procedures in the "Manual" should be followed.

6.35.00 SUBGRADE INVESTIGATION AND PAVEMENT DESIGN REPORT

The report shall be prepared by or under the supervision of and signed and sealed by a Professional Engineer registered in the State of Colorado and shall include the following information:

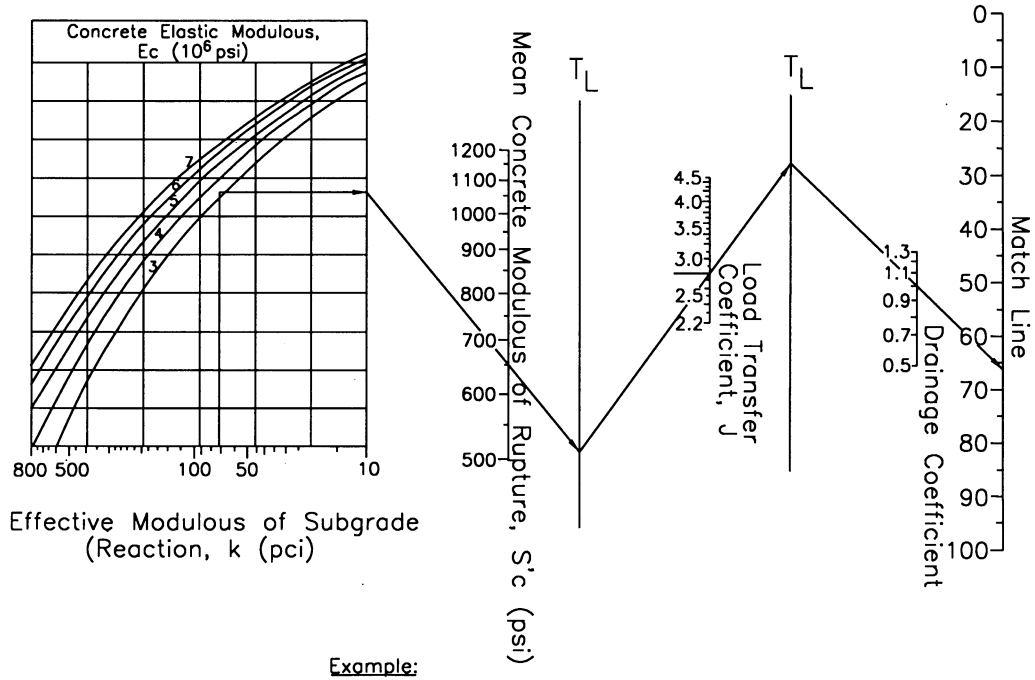
(A) Vicinity map to locate the investigated area.

(B) Scaled drawings showing the location of borings.

(C) Scaled drawings showing the estimated extent of subgrade soil types and EDLA for each street.

NOMOGRAPH SOLVES:

$$\log_{10} 18^{K} ESAL = Z_R * S_o + 7.35 * \log_{10}(D+1) - 0.06 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.5 - 1.5}\right]}{1 + \frac{1.624 * 10^7}{(D+1)^{8.46}}} + (4.22 - 0.32 p_t) * \log_{10}\left[\frac{S'c * Cd\left[D^{0.75} - 1.132\right]}{215.63 * J\left[D^{0.75} - \frac{18.42}{(Ec/k)^{0.25}}\right]}\right]$$



Example:

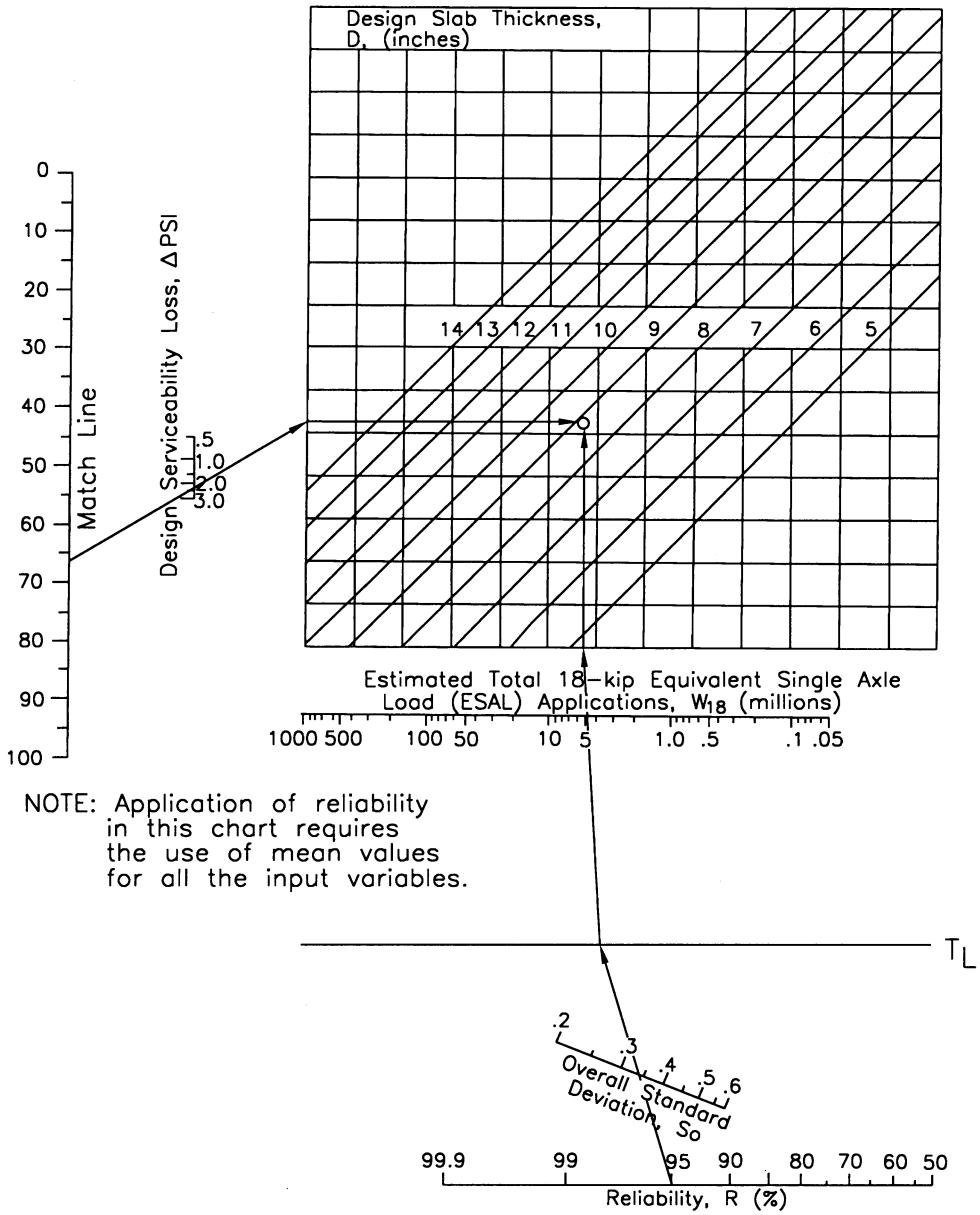
k = 72 pci
Ec = 3.4x10 psi
S'c = 650 psi
J = 2.8
Cd =1.0

So =0.34
ΔPSI = 4.0−2.5=2.0
18K ESAL = 5.1 X 10^6
Solution: D=9.0 inches (nearest half−inch, from segment 2)

Design chart for rigid pavement based on using mean values for each input variable(Segment 1)

TABLE 6.34.02

Rigid Pavement 2 of 2



Design chart for rigid pavements based on using mean values for each input variable (Segment 2).

(D) Pavement design alternatives for each street on a scaled drawing.

(E) Tabular listing of sample designation, sample depth, group number, liquid limit, plasticity index, percent passing the No. 200 sieve, AASHTO classification, group index, and soil description.

(F) CBR (R-value) test results of each soil type used in the design.

(G) Pavement design nomographs properly drawn to show soil support -- ESAL - SN.

(H) Design calculations.

(I) A discussion regarding potential subgrade soil problems including, but not limited to:

1. Heave or settlement-prone soil.

2. Frost-susceptible soils.

3. Ground water.

4. Drainage considerations (surface and subsurface).

5. Cold-weather construction (if appropriate).

6. Other factors or properties which could affect the design or performance of the pavement system.

(J) Recommendations to alleviate or mitigate the problems discussed in Items 1 through 6 above.

6.40.00 STREET CONSTRUCTION STANDARDS

6.41.00 GENERAL

The purpose of this section is to set forth the criteria to be used in the construction of all streets and appurtenances within the City of Westminster.

6.42.00 COMPACTION IN UTILITY TRENCHES

Before street construction will be permitted, the top four feet (4') of all utility trenches within the street right-of-way (including service lines) shall be compacted to ninety-five percent (95%) of maximum standard density and the balance of the trench compacted to ninety percent (90%) of maximum density, as determined by ASTM D 698-78 or as specified in the approved soils report. This compaction shall extend to the street right-of-way lines as a minimum. Water settlement of trenches shall not be permitted. All water and sewer services, including water and sewer main stub-outs, shall be installed prior to street construction except that curb and gutter and sidewalk shall be installed prior to water service line installation.

6.43.00 EXCAVATION AND EMBANKMENT

6.43.01 General

The intent of this section is to specify methods and standards to be used in the construction of embankments or excavations for City streets or for other purposes, as indicated on the approved drawings or contract documents. The work will include excavation, embankment, grading; compacting; clearing and grubbing; removal of topsoil, trees, stumps, or other vegetation; removal and/or resetting of minor obstructions; subgrade preparations; and any other work incidental for the construction of excavations and embankments. All workmanship and materials shall be in accordance with the requirements of these STANDARDS AND SPECIFICATIONS and in conformity with the lines, grades, quantities, and the typical cross-section shown on the plans or as directed by the City Engineer.

6.43.02 Clearing and Grubbing

Work shall consist of clearing, grubbing, removing and disposing of all vegetation and debris within the limits of the project, and such other areas as may be indicated on the approved plans or required by the work except such objects as are designated to remain or are to be removed in accordance with other sections of these STANDARDS AND SPECIFICATIONS. All surface objects and trees, stumps, roots, and other protruding obstructions not designated to remain shall be cleared and/or grubbed as required except non-perishable solid objects which shall be a minimum of two feet (2') below subgrade.

Except in areas to be excavated, stump holes and other holes from which obstructions are removed shall be backfilled with suitable material and compacted in accordance with these STANDARDS AND SPECIFICATIONS. Materials and debris shall be disposed of in a manner acceptable to the City Engineer. Burning shall not be permitted without prior written approval of the City Engineer, Fire Marshal and the county health department.

The contractor shall make all necessary arrangements for obtaining suitable disposal locations. If disposal will be at other than established dump sites, the City Engineer may require the contractor to furnish written permission from the property owner on whose property the materials and debris will be placed. Branches on trees or shrubs shall be removed as directed. Branches of trees extending over the road bed shall be trimmed to give a clear height of twenty feet (20') above the road bed surface. All trimming shall be done by skilled workmen and in accordance with good tree surgery practices.

The contractor shall scalp areas where excavation or embankment is to be made, except that mowed sod need not be removed where the embankment to be constructed is four feet (4') or more in height below subgrade elevation. Scalping shall include the removal of material such as brush, roots, sod, grass, residue of agricultural crops, sawdust, and other vegetable matter from the surface of the ground. Hedges shall be pulled or grubbed in such a manner as to assure complete and permanent removal. Sod not required to be removed will be thoroughly disked before construction of embankment.

6.43.03 <u>Removal of Existing Structures</u>

(A) The contractor shall raze, remove, and dispose of all foundations, signs, structures, fences, old pavements, abandoned pipe lines, traffic signal materials, and other obstructions which are within the project limits except for utilities and for those items which other provisions have been made for removal. Traffic signals and related materials will include all attachment hardware and other incidental materials such as, but not limited to, mast arms and span wire. Concrete adhering to sign posts shall be removed, and pedestals and bases shall be removed to one foot (1') below the surrounding ground or subgrade.

Where portions of structures are to be removed, the remaining portions shall be prepared to fit new construction. The work shall be done in accordance with plan details and in such a manner that materials to be left in place will be protected from damage. All damage to portions of structures which are to remain in place shall be repaired by the contractor at his expense. Reinforcing steel, projecting from the remaining structure, shall be cleaned and aligned to provide bond with new extension. Dowels shall be securely grouted with approved grout.

Removal of sign panel shall include all work necessary to remove the panel and its attachment hardware from the existing installation. Where culverts or sewers are to be left in place and plugged, the ends shall be filled with concrete. In addition, the entire length of pipe to be left in place shall be blown full of sand. Materials used in detour structures and supplied by the contractor shall be the property of the contractor. After the detour is abandoned, the contractor shall completely remove the detour structures and shall dispose of materials according to these STANDARDS AND SPECIFICATIONS.

(B) Bridges, culverts, and other drainage structures in use by traffic shall not be removed until satisfactory arrangements have been made to accommodate traffic. Unless otherwise directed, the substructures of existing structures shall be removed to one foot (1') below natural stream bottom or ground surface. Where such portions of existing structures lie wholly or in part within the limits of a new structure, it shall be removed as necessary to accommodate the construction of the proposed structure. Steel, precast concrete, and wood bridges shall be carefully dismantled without unnecessary damage. Steel members to be salvaged shall be match-marked with waterproof paint.

(C) Unless otherwise provided, all pipe shall be carefully removed and cleaned. Every precaution shall be taken to avoid breaking or damaging the pipe. Pipes to be relaid shall be removed and stored, when necessary, so that there will be no loss or damage before relaying. When removing manholes, catch basins, and inlets, any live sewer connected to these items shall be properly reconnected and satisfactory bypass service shall be maintained during such operation.

(D) Concrete or asphalt concrete that is to remain shall be cut in a straight, true line with a vertical face. The contractor shall be responsible for the cost of removal and replacement of all overbreak. Sawing shall be done carefully, and all damages to concrete or asphalt to remain in place, which are caused by the contractor's operations, shall be repaired by the contractor at his expense. The minimum depth of saw cuts in

concrete shall be two inches (2"). If the removed portion falls within five feet (5') of an existing joint or edge, the concrete shall be removed to that joint or edge.

6.43.04 Salvage

All salvageable material shown on the plans shall be removed without unnecessary damage in sections or pieces which may be readily transported and shall be stored by the contractor in locations approved by the City Engineer. The contractor shall be required to replace any materials lost from improper storage methods or damaged by negligence.

6.43.05 Disposal

The contractor shall make all necessary arrangements for obtaining suitable disposal locations, and the cost involved shall be included in the work. If disposal will be at other than established dump sites, the City Engineer may require the contractor to furnish written permission from the property owner on whose property the materials will be placed.

6.43.06 Excavation and Embankment

Excavation of whatever substances that are encountered within the limits of the project shall be performed to the lines and grades indicated on approved plans. All excavated areas shall be graded in a manner that will permit adequate drainage. Whenever practicable, all suitable material removed from the excavations shall be used in the formation of embankments, for backfilling, and for other approved purposes. Where material encountered within the limits of the work is considered unsuitable, such material shall be excavated below the grade shown on the approved drawings or as directed by the City Engineer and replaced with suitable material. All unsuitable excavated materials and any surplus or excavated material which is not required for embankments shall be disposed of by the contractor.

Before any embankment is placed, clearing, tree removal, sod and topsoil removal over the entire area shall be performed in accordance with these STANDARDS AND SPECIFICATIONS. The base of fill areas shall be scarified to a depth of not less than six inches (6") prior to placement of embankment material. Each layer shall be wetted or aerated, if necessary. No embankment material shall be placed upon organic, spongy, or frozen material or other material unsuitable for the placement thereof in the opinion of the City Engineer. When an embankment is to be placed on slopes, it shall be continuously benched in horizontal layers to key to the existing slopes.

The construction of embankments by deposition, placing, and compacting materials of acceptable quality above the natural ground or other surface shall be in accordance with the lines, grades, and cross-sections shown on the approved plans and/or as required by the City Engineer. Each lift of the embankment material shall not exceed eight inches (8") in loose depth. The contractor shall thoroughly mix the different materials to secure a uniform moisture content and to insure uniform density and proper compaction. Each layer shall be thoroughly compacted by roller or vibratory equipment which is suitable for the type of embankment material to the densities specified below:

TABLE 6.43.06 *

AASHTO M145 Soil Classification	AASHTO T99 Minimum Relative Compaction (Percent)	AASHTO T180 Minimum Relative Compaction (Percent)
A-1	100	95
A-3	100	95
A-2-4	100	95
A-2-5	100	95
All Others	95	90

* Table 6.43.06 taken from Colorado Department of Transportation Specifications Section 203.07

Class I structural backfill shall be used on all bridges, box culverts, or where otherwise specified. All other backfill shall be developed on site.

6.43.07 Select Borrow Material

In the event the material found on site is unsatisfactory for constructing subgrade, embankments, or filling excavations, the contractor shall provide material from off-site. The selected borrow material shall be a well-graded mixture of sound mineral aggregate particles containing sufficient quality bonding material to secure a firm stable foundation when placed and compacted on the roadway. The R-value of the borrow shall be equal to or greater than the design R-value required for the street. The R-value of the borrow shall be provided to the City Engineer prior to placing borrow. If tests reveal that material being placed is not of suitable quality and structural value, the contractor shall provide other material as approved by the City Engineer.

6.44.00 SUBGRADE PREPARATION AND GRADING

6.44.01 General

The work covered by this section concerns the furnishing of all labor, equipment, supplies, and materials needed to perform preparation of subgrade within the public right-of-way. The bottom of the excavation for the pavement, or top of the fill, will be known as the pavement subgrade and shall conform to the lines, grades, and cross-sections shown on the approved plans. Prior to the street being excavated, all service cuts shall be checked to see if the backfill meets density requirements. If deficient, they shall be recompacted and brought up to the density as specified in Chapter 9, Trenching , Backfilling and Compaction.

6.44.02 Subgrade Stabilization

Embankment and subgrade soils shall be compacted to ninety-five percent (95%) of maximum standard density at plus or minus two percent (±2%) optimum moisture or as recommended in the approved soils report. Maximum density shall be determined by ASTM D 698-78. Soft and yielding material and other portions of the subgrade which will not compact when rolled or tamped shall be removed as directed by the City Engineer and replaced with suitable material.

Subgrade surfaces below excavated areas such as cut areas and undisturbed areas shall require additional preparation. Said subgrade shall be scarified to a minimum depth of twelve inches (12"), wetted or aerated as needed, and compacted until the required density is obtained, unless otherwise approved by the City Engineer. No paving, subbase, or base shall be placed on soft, spongy, or frozen unstable subgrade which is considered unsuitable by the City Engineer.

The contractor shall, when requested by the City Engineer, furnish the necessary equipment to proof roll, even though density tests may indicate compliance. Heavy construction equipment or loaded trucks acceptable to the City shall be driven over the finished subgrade and deflections noted. Soft and yielding material and portions of the subgrade which show deflection shall be scarified and re-rolled or shall be removed and replaced with subgrade course material and then placed and compacted as specified herein. Subgrade shall not be approved for base course construction or paving until it is uniformly stable and unyielding.

6.44.03 Lime and Cement Treated Subgrade

When recommended by the approved soils report and/or pavement design, the surface of the road bed shall be bladed to the established lines, grades, and cross-sections as shown on the approved plans. The prepared road bed shall be scarified to the depth and width required for the subgrade stabilization. The material thus obtained shall be pulverized. Application, mixing, and finishing shall be in accordance with Colorado Department of Transportation Specifications, 1991 Edition, Section 307.04 through 307.07. Hydrated lime shall conform to the requirements of ASTM C 107-79, Type N.

6.44.04 Subgrade Surface Tolerance

The excavation and embankments for the street, intersections, and driveways shall be finished to a reasonably smooth and uniform surface. Variations from the subgrade shall not be more than one-half inch (1/2") in solid nor more than one inch (1") above or six inches (6") below in rock.

6.45.00 SUBBASE CONSTRUCTION

6.45.01 General

The subbase shall consist of a foundation course composed of granular material constructed on the prepared subgrade in accordance with these STANDARDS AND SPECIFICATIONS and in reasonable conformity to the lines and grades and typical cross-sections as shown on the approved plans.

6.45.02 Placement and Compaction

Each layer of subbase material shall be placed in layers not to exceed six inches (6") in compacted depth. Each layer shall be wetted or aerated, if necessary, and compacted to ninety-five percent (95%) maximum density at plus or minus two percent ($\pm$2%) of optimum moisture as determined by ASTM D 698-78. No subbase material shall be placed upon a soft, spongy, or frozen subgrade or other subgrade, the stability of which is unsuitable for the placement thereof.

6.45.03 Subbase Surface Tolerance

The prepared surface of the subbase shall not vary from the approved grade by more than a half inch (1/2").

6.46.00 BASE CONSTRUCTION

6.46.01 General

The intent of this section is to specify methods to be used for the construction, overlaying, sealcoating, and pavement rejuvenating of streets, parking lots, walks, drainageways, and other miscellaneous work requiring the use of aggregates. The work covered shall include general requirements that are applicable to aggregate base course, bituminous base, and pavements of the plant-mix type, bituminous prime coat, bituminous tack coat, rejuvenating applications, and asphalt concrete overly. All workmanship and material shall be in accordance with requirements of these STANDARDS AND SPECIFICATIONS and in conformity with the lines, grades, depths, quantity requirements, and the typical cross-section shown on the approved plans or as directed by the City Engineer.

6.46.02 Base Course

This item shall consist of a foundation course composed of crushed gravel or crushed stone and filler, constructed on the prepared subgrade or subbase course. Construction shall be in accordance with the requirements of the Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction, Section 304 and the approved pavement design. The composite base course material shall be free from vegetation and lumps or balls of clay.

6.46.03 Placement and Compaction

The base course material shall be deposited and spread in a uniform layer without segregation of size to a compacted depth not to exceed six inches (6"). The material shall be compacted to a minimum ninety-five percent (95%) density as determined by ASTM D 698-78. No base course material shall be placed upon a soft, spongy, or frozen subgrade or subbase with an unsuitable stability. Base material shall not be placed on a dry or dusty foundation where the existing condition would cause rapid dissipation of moisture from the base material and hinder or preclude its proper compaction. Such dry foundations shall have water applied and shall be reworked and recompacted.

Rolling shall be continuous until the base material has been compacted thoroughly in accordance with these STANDARDS AND SPECIFICATIONS. Water shall be uniformly applied as needed during compaction to obtain optimum moisture content and to aid in consolidation. The surface of each layer shall be maintained during the compaction operations in such a manner that a uniform texture is produced and the aggregates are firmly placed.

6.46.04 Base Surface Tolerance

The prepared surface of the base shall not vary from the approved grade by more than one-half inch (1/2").

6.47.00 BITUMINOUS CONSTRUCTION

6.47.01 Hot Bituminous Pavement

All pavement shall be hot bituminous pavement of the plant mix type unless otherwise approved in writing by the City Engineer. Construction shall be in accordance with the Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction, Section 403, and the following requirements:

(A) The asphalt cement shall be in accordance with Section 6.73.02 (A) of these STANDARDS AND SPECIFICATIONS.

(B) The gradation of the mineral aggregate shall be in accordance with Section 6.73.02 (B) of these STANDARDS AND SPECIFICATIONS.

6.47.02 Tack Coat

When tack coat is specified on the approved plans or required by the City Engineer, all construction shall be in accordance with the requirements of the Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction, Section 407. Bituminous material shall be applied at the rate of five one-hundredths (0.05) to fifteen one-hundredths (0.15) gallons per square yard.

6.47.03 Seal Coat

When seal coat is required, all construction shall be in accordance with the requirements of the Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction, Section 409. The type of bituminous material, cover aggregate, and rate of application shall be as shown on the approved construction plans.

6.47.04 Rejuvenating Agent

When a rejuvenating agent is specified on the approved construction plans or required by the City Engineer, all materials and construction shall be in accordance with the requirements of the Colorado Department of Highways' Standard Specifications for Road and Bridge Construction, Section 407. The rejuvenating agent shall be as shown on the approved construction plans or as specified by the City Engineer.

6.47.05 Heating and Scarifying

When heating and scarifying treatment is specified on the approved construction plans or required by the City Engineer, all materials and construction shall be in accordance with requirements of the Colorado Department of Transportation's Standard Specifications for Road and Bridge Construction, Section 405.

6.47.06 Grinding

Grinding shall consist of milling, grinding, or cold planing the existing pavement surface to establish a new surface profile and cross-section in preparation for a bituminous overlay. After grinding, the surface shall have a grooved or ridged finish, uniform, and resistant to raveling or traffic displacement. This textured surface shall have grooves of one-quarter inch (1/4") plus or minus one-eighth inch (±1/8).

Wedge cut grinding shall consist of grinding the existing pavement surface a minimum of four feet (4') wide at the existing concrete gutter. The edge of the gutter end of the finished wedge cut shall be one-and-one-half inches (1-1/2") below the edge of the existing concrete gutter. The centerline of the street edge of the wedge cut will be cut one-eighth inch (1/8"). The depth of cut shall be determined by measuring to the top of the ridges by placing a five-foot (5') straight edge perpendicular to the grooving pattern. Full-width grinding shall consist of grinding the existing pavement surface from edge of gutter to edge of gutter to a minimum depth of two inches (2") unless otherwise directed by the City Engineer.

In grinding around utility castings, the contractor may choose to remove the entire existing bituminous pavement around the castings where grinding is not completed and replace it with bituminous surface course placed and compacted in three-inch (3") lifts. The contractor shall vertically cut the limits of the area to be patched, mechanically compact the existing base course, and prime the bottom and vertical edges before backfilling. The contractor shall remove the cuttings immediately behind the grind machine by belt loader, end loader, power sweeper, and/or by hand. The removed material shall be disposed of as approved by the City Engineer.

The grinding machine shall be a power-operated, self-propelled machine having a cutting drum with lacing patterns that will attain a grooved surface and produce grinding chips of less than one inch (1") in size. The grinding machine shall be equipped with a pressurized watering system for dust control. The equipment shall be a type that has successfully performed similar work.

The cleaning equipment shall be a type which will efficiently remove all loosened material and load into trucks for hauling and spreading. Because of the nature of the streets to be ground and the traffic restrictions, a belt loader followed by a power sweeper and manual sweeper is the most desirable method. Flushing into the City's storm sewer system as a means of clean-up will not be allowed.

6.48.00 PORTLAND CEMENT CONCRETE PAVEMENT

6.48.01 General

Work covered by this section consists of furnishing all tools, transportation, labor, equipment, accessories, services and material, and in performing all operations in constructing a single course of air-entrained Portland cement concrete pavement constructed on a prepared subgrade in accordance with these STANDARDS AND SPECIFICATIONS and in conformity with the lines, grades, thickness, and typical cross-sections as shown on the contract documents. **Portland Cement Concrete Pavements will only be allowed if approved in writing by the City Engineer.**

6.48.02 Method

Construction may be of either of the following methods:

(A) **Standard Concrete Pavement:**

Standard concrete pavement shall consist of concrete of the type and thickness in the other contract documents, placed within fixed forms, and consolidated and finished by equipment operating on forms. This method is only to be used with written permission of the City Engineer.

(B) **Slip-Form Pavement:**

Slip-form pavement shall consist of concrete of the type and thickness specified in the other contract documents placed, consolidated, and finished without the use of fixed forms. Unless specifically permitted in the contract documents, the use of slip-form type paving equipment shall be by permission of the City Engineer only.

6.48.03 Setting Forms

(A) **Base Support:**

The foundation under the forms shall be hard and true to grade so that the form, when set, will be firmly in contact for its whole length and at the specified grade. Any grade which at the form line is found below established grade shall be filled to grade with granular material in lifts of one-half inch (1/2") or less for a distance of eighteen inches (18") on each side of the base of the form and thoroughly compacted. The granular material shall meet the ASTM D 4253 specification (<10 percent passing the No. 200 sieve). Imperfections or variations above grade shall be corrected by tamping or by cutting as necessary.

(B) **Form Setting:**

Forms shall be set sufficiently in advance of the point where concrete is being placed. After the forms have been set to correct grade, the grade shall be thoroughly tamped, mechanically or by hand, at both the inside and outside edges of the base of the forms. Forms shall be staked into place with not less than three pins for each ten-foot (10') section. A pin shall be placed at each side of every joint. Form sections shall be tightly locked, free from play or movements in any direction. The forms shall not deviate from true line by more than one-quarter inch (1/4") at any point. Curb forms shall remain in place at least six hours after curb is placed. The curb form shall extend the vertical plane one-eighth inch (1/8"). No excessive settlement or springing of forms under the finishing machine will be tolerated. Forms shall be cleaned and oiled prior to the placing of concrete.

(C) **Grade and Alignment:**

The alignment and grade elevations of the forms shall be checked and corrections made by the contractor immediately before placing the concrete. When any form has been disturbed or any grade has become unstable, the form shall be reset and rechecked by the contractor.

6.48.04 <u>Subgrade Planing</u>

(A) After the setting of forms has been approved, the subgrade shall be fine graded with a subgrade planer or electronically controlled trimmer to correct the crown and elevation. Any excess material, as indicated by this template, shall be removed. To bring low areas up to the correct elevation, approved material shall be furnished. The existing subgrade in low areas shall be tamped or rolled in place until thoroughly compacted. Use of a rubber-tired roller is encouraged. Any ruts and depressions which develop shall be filled and consolidated.

(B) Equipment of such weight or used in such a way as to cause ruts in the finished subgrade two inches (2") or more in depth shall be removed from the work or the rutting otherwise prevented.

(C) Unless waterproof subgrade or base course cover material is specified, the subgrade or base course shall be uniformly moist when the concrete is placed. If it subsequently becomes too dry, the subgrade or base course shall be sprinkled but the method of sprinkling shall not be such as to form mud or pools of water. Over-saturated subgrade areas that are creating excessive wheel tracking by concrete hauling equipment, as determined by the City Engineer, shall be removed and replaced with appropriate select material prior to placement of the concrete pavement.

6.48.05 <u>Placing Concrete</u>

(A) Concrete which has developed initial set or does not have workable consistency shall not be used.

(B) The contractor shall take necessary precaution to prevent segregation of concrete when discharged. Conveying equipment shall be washed and kept clean at all times.

(C) The concrete shall be deposited to such depth that, when consolidated and finished, the slab will not be below grade at any point. The concrete shall be deposited to require as little rehandling as possible. Necessary hand-spreading shall be done with shovels.

(D) The contractor shall be required to exercise such care in placing, vibrating, compacting, and finishing concrete at and about all transverse expansion joints and adjacent to side forms as to avoid damage to joint material and the forming of honeycomb and voids. Concrete shall not be dumped directly over or against a joint or in such a manner that the concrete will flow directly against the expansion joint. Concrete shall be shoveled against both sides of expansion joints simultaneously. The vibratory unit shall not be allowed to operate while the finishing machine or spreader is standing still, except at transverse joints where vertical joint material is used, where a short pause shall be made on both sides of the joint to consolidate the concrete.

(E) The consistency of concrete shall be kept uniform for each class of work and shall be checked by means of slump tests or Kelly ball tests. The workability of the concrete shall be varied as directed by the City Engineer. At all times, concrete shall have a consistency such that it can be worked into corners and angles of the forms and around joints, dowels, and tie bars by the construction methods which are being used without excessive spading, segregation, or undue accumulation of water or laitance on the surface. If, through accident, intention, or error in mixing, any concrete fails to conform to the proportions of the approved mix design, such concrete shall not be incorporated in the work but shall be discarded off the project site as waste material at the contractor's expense. NO WATER SHALL BE ADDED AT THE JOB SITE WITHOUT PERMISSION OF AN APPROPRIATE CITY OFFICIAL. If approval is obtained and water is added at the job site, slump tests shall be run and test cylinders cast following the addition of water. Any expense incurred in excess of ordinary tests shall be borne by the contractor.

(F) Concrete shall not be placed when darkness will prevent good workmanship in placing and finishing operations. In good weather the header shall be placed at least forty-five (45) minutes before sunset. During cold weather more time shall be allowed for finishing and protection. All finishing and curing operations shall be performed prior to darkness.

(G) At the time of concrete placement the mix temperature shall be between fifty and ninety degrees Fahrenheit (50° F and 90° F).

(H) Concrete paving machines weighing more than five thousand (5,000) pounds shall not be utilized on freshly poured concrete slabs for adjacent and abutting pours until seventy-two (72) hours have elapsed. This time requirement shall be increased to seven (7) days when the concrete paving machine weights more than thirty thousand (30,000) pounds.

6.48.06 <u>Weather Restrictions</u>

(A) **Hot Weather:**

Except by written authorization from the City Engineer, concrete shall not be placed if the temperature of the plastic concrete cannot be maintained at ninety degrees Fahrenheit (90ºF) or lower. The placement of concrete in hot weather shall comply with ACI 305.

(B) **Cold Weather:**

During extreme weather conditions, placing of concrete will be permitted only when the temperature of the concrete placed in the forms will not be less than fifty degrees Fahrenheit (50ºF) nor more than ninety degrees Fahrenheit (90ºF). To maintain this temperature range, the contractor shall provide acceptable heating apparatus for heating the aggregates and the water. Concrete slabs shall not be placed regardless of temperature conditions if the supporting ground is frozen or contains frost. Use of salt or other additives to prevent concrete from freezing will not be allowed. Concrete which has been frozen shall be completely removed and replaced as directed by, and to the satisfaction of, the City Engineer.

Concrete may be placed when the air temperature in the shade is at least forty degrees Fahrenheit (40ºF) and rising. No concrete shall be placed, regardless of the present temperature, when the weather forecast promises freezing weather before final set of the concrete unless special means of heating and protection are used. Protection against freezing is the contractor's responsibility regardless of the weather forecast or climatic conditions at the time of placing.

During cold weather conditions, concrete less than seventy-two (72) hours old shall be protected as follows:

TABLE 6.48.06
Forecasted Low Temperature

by National Weather Service	Protection
Between 40 and 32 Degrees	One layer of plastic or burlap.
Between 31 and 25 Degrees	One layer of plastic and one layer of burlap, or two layers of burlap.
Below 25 Degrees	Six inches (6") of hay or straw and two layers of plastic or burlap in addition to regular curing method, or equivalent commercial insulating material in addition to regular curing method. Those coverings shall remain in place until the concrete is at least five (5) days old. When straw is required on pavements, cured with only curing compound, the fresh concrete shall be covered with a layer of burlap or plastic before application of straw. Heated enclosures may be utilized in lieu of protection requirements cited above. If used, such enclosures shall be maintained for seven (7) days.

6.48.07 Mesh Reinforcement

(A) Mesh reinforcement, if required by the approved plan or other contract documents, shall be free from dirt, rust, scale, paint, grease, oil, or other foreign substances when placed in work.

(B) A screed or template shall be used to roughly strike off the first layer of concrete at one-half the specified thickness to permit placing the mesh reinforcement.

(C) Reinforcing mesh shall be placed at the midpoint of the concrete slab and be parallel to the finished surface. The mesh can be elevated using either bricks or chairs. Adjacent sheets shall lap at least the length of one spacing of the fabric in all directions. Reinforcing shall extend to within three inches (3") of the edge of the concrete but shall not cross expansion joints. The balance of the concrete shall then be placed, leveled, vibrated, and finished.

6.48.08 <u>Joints</u>

(A) **General:**

1. The contractor shall submit a construction joint pattern for approval. The pattern shall be based upon these STANDARDS AND SPECIFICATIONS.

2. Expansion and contraction joints shall be so constructed as to be continuous across all lanes, not staggered. The saw-cuts shall be one-fourth (1/4) of the thickness of the slab for the entire width of the concrete. The joints shall not be sawed until the concrete has hardened to the extent that tearing and raveling are precluded nor later than the day the protective coating, if any, is removed or that random cracking would be likely to occur if the joint were not sawed. Any procedure which results in premature and uncontrolled cracking shall be revised immediately by adjusting the sequence of sawing the joints or the time interval involved between the placing or the concrete and the sawing of joints.

(B) **Transverse Contraction Joints:**

1. Sawed transverse contraction joints shall be spaced at fifteen-foot (15') centers when nominal slab thickness is less than eight inches (8"). They shall be at twenty-foot (20') centers when slab thickness is eight inches (8") or greater.

2. Formed contraction joints spaced at forty-five foot (45') to ninety-foot (90') centers shall be used when expected air temperatures during the first twenty-four (24) hours after the concrete is placed will be more than twenty degrees Fahrenheit (20°F) less than the temperature of the concrete at the time the concrete is placed. Sawed contraction joints shall be spaced evenly between formed contraction joints after the concrete has set sufficiently to allow sawing.

(C) **Transverse Expansion Joints:**

Normally, transverse expansion joints will be used at the beginning of radii at "T" intersections. Expansion joints shall consist of three-quarter-inch (3/4") smooth steel dowel bars, sixteen inches (16") long, spaced at twelve-inch (12") centers inserted through one-inch (1") non-extruding expansion material and supported by a performed dowel basket. Expansion material shall separate the two slabs with approximately one inch (1") of expansion material extending below the top of the subgrade. Dowel caps shall be placed over the greased ends of dowels that extend into the last slab poured at expansion joints. Reinforcing mesh shall terminate three inches (3") from the expansion joint and resume three inches (3") from the expansion material on the other side of the joint. Under no circumstances shall any concrete be left above the expansion material or across the joints at any point. All concrete spanning the ends of the joint next to the forms shall be carefully cut away after the forms are removed. Before the pavement is open to traffic, the groove above expansion joints shall be cleaned and sealed with joint-sealing material.

(D) **Longitudinal Contraction Joints:**

Longitudinal contraction joints will normally be constructed in the same manner as sawed transverse contraction joints. When located at the center of the pavement slab, one-half inch (1/2") deformed bars, thirty inches (30") long, shall be placed on thirty-inch (30") centers.

(E) **Transverse Construction Joints and Emergency Headers:**

Whenever the work of concreting stops for thirty (30) minutes or more, a header, the top of which is true to the shape and grade of the finished pavement, shall be set in a vertical position at right angles to the centerlines of the pavement. This header should line up with adjacent joints. The concrete shall be poured up to the header, spaded, vibrated, or tamped into place so as to leave no porous place in the concrete. Smooth steel dowel pins, three-quarter inches (3/4") in diameter, sixteen inches (16") long shall be placed at intervals of one foot (1') on the center height of the pavement for a distance of eight inches (8") into the concrete. When work is resumed, the header shall be removed without disturbing the concrete or rods. The fresh concrete shall be placed directly against the face of the previously poured concrete and well-spaced around the rods.

(F) **Permanent Headers:**

If a header is at the end of the project, the end of an intersection return, or if paving operations are to be suspended for thirty (30) days or more, the header board may be left in place and concrete placed over the dowel bars until such time as paving operations are resumed at the header.

(G) **Keyed Longitudinal Construction Joints:**

If the pavement width is placed in more than one pour then a longitudinal construction joint shall be constructed of one-half-inch (1/2") round, deformed bars two feet six inches (2'-6") long at two-foot six-inch (2'-6") centers; bent at ninety degrees (90°) in the center; placed at the midpoint in the slab; one leg to extend at right angles to the centerline into the first pour; and parallel to the finished grade. The other leg shall be parallel to the edge and separated from the first pour by means of continuous fiber or metal key board. Prior to pouring the second half of the pavement, the bars shall be straightened. Care must be used in straightening the bars to not injure the concrete already in place. Bars shall not be straightened until the concrete has reached the age of twenty-four (24) hours when the air temperature is continuously higher than fifty degrees Fahrenheit (50°F). If the air temperature is lower than fifty degrees Fahrenheit (50°F) at any time during the first twenty-four (24) hours, then seventy-two (72) hours must elapse before the bars may be straightened.

(H) **Cleaning and Sealing Joints and Cracks:**

1. All joints to be sealed shall be sound, clean, dry, and frost free. Joints shall be thoroughly cleaned to remove any laitance or any foreign materials. Freshly sawed joints shall be washed with high-pressure water immediately after sawing to remove any loose material from the joint faces. Joint washing should be in one direction to prevent recontamination. Just before installing the backer rod, all joints shall be sandblasted and then blown out with compressed air at a pressure of at least ninety (90) psi. Air compressors used for this purpose shall be equipped with traps capable of removing moisture and oil from the air. Sealing shall be performed in accordance with the manufacturer's directions. The sealant manufacturer's representative shall be present at the start of work at the discretion of the City Engineer.

2. Sealant shall be approved prior to application by the City Engineer.

3. Hot-poured joint sealer material for concrete slab joints shall conform to the requirements of ASTM d 3405, latest edition, and to the following: "The shipping containers shall be marked by the manufacturer with the name of the material, the name and brand of the manufacturer, the weight, the batch number, and the safe heating temperature." The temperature at pour point shall be lower than the safe heating temperature by at least twenty degrees Fahrenheit (20ºF).

   The sealer material shall be melted in a heating kettle or tank constructed as a double boiler with a space between the inner and outer shells filled with oil, asphalt, or other material for heat transfer and for positive temperature control. The heating and melting unit shall be equipped so that the heat may be adjusted to provide control of the temperature of the heating medium used for melting the sealer material. The sealer material shall not be subjected to temperatures in excess of four-hundred-and-fifty degrees Fahrenheit (450ºF) at any stage or time during the melting operations.

6.48.09 <u>Final Strike-Off, Consolidation and Finishing</u>

(A) **Sequence:**

The sequence of operations shall be the strike-off and consolidation, floating and removal of laitance, straight-edging, and final surface finish. Unless permitted by the City Engineer, the addition of superficial water to the surface of the concrete to assist in finishing operations will not be permitted. If the application of water to the surface is directed by the City Engineer, it shall be applied as a fog spray by means of accepted spray equipment.

(B) **Finishing at Joints:**

1. The concrete shall be placed under and around all applicable load transfer devices, joint assembly units, and other features designed to extend into the pavement. Concrete adjacent to joints shall be mechanically vibrated.

2. After the concrete has been placed and vibrated, the finishing machine shall be brought forward, operating in such manner to avoid damage to joints. If operation of the finishing machine appears to be causing damage to the joints, the machine shall be stopped when the front screed is approximately eight inches (8") from the joint. The front screed shall be lifted, set directly on top of the joint, and the forward motion of the finishing machine resumed. When the second screed is close enough to permit the excess mortar in front of it to flow over the joint, it shall be lifted and carried over the joint. Another pass with the finishing machine over the joint without lifting the screeds will be required.

(C) **Consolidation and Finishing:**

The concrete shall be sufficiently and uniformly vibrated so that the density of Class P concrete is not less than ninety-seven percent (97%) of maximum theoretical field density. The density of Class AX concrete shall not be less than ninety-four percent (94%) of maximum theoretical field density.

Unless otherwise specified, hand-finishing methods will not be permitted except under the following conditions:

1. In the event of breakdown of the mechanical equipment, hand methods may be used to finish the concrete already deposited on the grade when the breakdown occurs.

2. Narrow widths or areas of irregular dimensions where operations of the mechanical equipment is impractical may be finished by hand methods.

Upon review by the City Engineer, the slump (consistency) may be increased up to one inch (1") above the maximum allowed in Table 6.77.04 for concrete in areas not accessible to mechanical finishing methods. Concrete shall be struck off and screed as soon as placed. Consolidation shall be attained by the use of a suitable vibrator or other acceptable equipment. In operation, the screed shall be moved forward on the forms with a combined longitudinal and transverse shearing motion and manipulated so neither end is raised from the side forms during the striking off process. If necessary, this shall be repeated until the surface is of uniform texture, true to grade, and cross-section end free from porous areas. The use of vibrating roller screed-type machines will be permitted for ramps and other areas not accessible to normal finishing methods.

(D) **Floating:**

After the concrete has been struck off and consolidated, it shall be further smoothed, trued, and consolidated as described below. Aluminum floats will not be permitted. The contractor may use a machine composed of a cutting and smoothing float, or floats, suspended from and guided by a rigid frame. The frame shall be carried by four or more visible wheels riding on and constantly in contact with the side forms. If necessary, long-handled floats having blades not less than five feet (5') in length and four inches (4") in width may be used to smooth and fill in open-textured areas in the pavement. Such long-handled floats shall not be used to float the entire surface of the pavement. After floating, any excess water and laitance shall be removed from the surface of the pavement by a scraping straight edge ten feet (10") or more in length. Successive drags shall be lapped one-half the length of the blade.

(E) **Straight-Edge Testing and Surface Correction:**

After the floating has been completed and the excess water removed but while the concrete is still plastic, the surface of the concrete shall be tested for trueness with a ten-foot (10') straight edge. For this purpose, the contractor shall furnish and use an accepted accurate ten-foot (10’) straight edge swung from handles three feet (3') longer than one-half the width of the slab. The straight edge shall be held in contact with the surface in successive positions parallel to the road centerline and the entire area gone over from one side of the slab to the other as necessary. If the entire slab cannot be reached from the side, a working bridge shall be provided to enable this testing to be accomplished the full width of the slab. Advance along the road shall be in successive stages of not more than one-half the length of the straight edge. Any depressions found shall be immediately filled with freshly-mixed concrete, struck off, consolidated, and refinished.

High areas shall be cut down and refinished. Special attention shall be given to assure that the surface across joints meets the requirements for smoothness and cross-slope. Straight-edge testing and corrections shall continue until the entire surface is found to be free from observable departures from the straight edge and the slab conforms to the required grade and cross-section. This straight-edge testing and correction operation shall be a separate operation from that described in the subsection on "Floating."

(F) **Final Finish:**

After the surface has been straight-edge tested and corrections made, a seamless strip of damp burlap or other accepted material shall be dragged longitudinally along the full width of pavement and curb to produce a uniform surface of gritty texture. For pavement sixteen feet (16') or more in width, the drag shall be mounted on a bridge which travels on the forms. The dimensions of the drag shall be such that a strip of material at least three feet (3') wide is in contact with the full width of the pavement surface while the drag is used. The drag shall consist of sufficient layers of material and maintained in such condition that the resultant surface finish is of uniform appearance and reasonably free from grooves over one-sixteenth inch (1/16") in depth. Where more than one layer of drag material is required, the bottom layer shall be approximately six inches (6") wider than the layer above. Drags shall be maintained

clean and free from encrusted mortar. Drags that cannot be cleaned shall be discarded and new drags substituted.

(G) **Edging at Forms and Joints:**

After the final finish but before the concrete has taken its initial set, the edges of the pavement along each side of each slab and on each side of expansion joints shall be worked with an accepted tool. A well-defined and continuous radius shall be produced and a smooth, dense mortar finish obtained. The surface of the slab shall not be unduly disturbed by tilting of the tool during use. At all joints, any tool marks appearing on the slab adjacent to the joints shall be eliminated by brooming the surface. In doing this, the rounding of the corner of the slab shall not be disturbed. All concrete on top of the joint filler shall be completely removed.

6.48.10 <u>Surface Smoothness Test</u>

The final riding surface shall meet the following tolerances:

Class I surfaces shall have a Section PI of no more than 14 inches/mile and a deviation of no more than 0.5 inches in 25 feet. Class II surfaces shall have a Section PI of no more than 18 inches/mile and a deviation of no more than 0.5 inches in 25 feet.

As soon as the concrete has sufficiently hardened, mainline pavement surfaces shall be tested to determine the Profile Index (PI) by using the profilograph method prescribed in Subsection 6.48.10(a). All other pavement surfaces are subject to testing using the 10-foot straight edge method prescribed in Subsection 6.48.10(b). Surfaces not meeting the requirements of Subsection (a) and (b) shall be corrected in accordance with Subsection 6.48.10(c).

Mainline pavement surfaces are defined as follows:

(1) Class I mainline surfaces consist of all through traffic and climbing lanes including bridges and bridge approach slabs with final riding surfaces of concrete. Excluded are the portions on horizontal curves having a centerline radius of curvature less than 1,000 feet and areas within the superelevation transition to such curves.

(2) Class II mainline surfaces consist of all acceleration and deceleration lanes, ramps, tapers, shoulders wider than six feet without rumble strips, and surfaces excluded from Class I due to horizontal curvature.

All other surfaces consist of shoulders that are six feet wide or less, shoulders with rumble strips, side street returns, or other small sections of pavement for which the use of a profilograph is not practical.

(A) Profilograph Method

The Contractor shall provide, operate and maintain on the project an approved multi-wheel profilograph that meets the requirements of Colorado Procedure 64. The profilograph shall be an approved computer equipped model.

The Contractor shall make arrangements, and payment if required, for the manufacturer of the profilograph that will be utilized on the project to conduct training for Contractor and City project personnel in the calibration, operation and maintenance of the profilograph. The training shall be conducted on the project at least three days before the start of any concrete pavement work. The representative of the profilograph manufacturer that conducts the training shall issue each individual attendee a letter stating that they have been trained in the calibration, operation and maintenance of the specific profilograph being used on the project.

The Contractor's operator shall have attended the aforementioned training and have a letter so stating. The Contractor's operator shall follow the manufacturer's instructions and shall measure and record profiles in accordance with Colorado Procedure 64 and this specification. The profilograph shall be operated at a speed of less than three miles.

The profilograph shall be calibrated after transportation and before each day's use in accordance with the manufacturer's instructions and Colorado Procedure 64.

During the initial paving operations, either when starting up or after a long shut down period, or when directed, the Contractor shall test the surface with the profilograph as soon as the concrete surface has sufficiently hardened to allow testing. This procedure shall continue until the Profile Index (PI) is equal to or less than the maximum pavement surface smoothness tolerance and the Engineer has accepted the Contractor's paving methods and equipment.

During normal daily paving operations, the pavement surface shall be tested as soon as possible, preferably during the next working day following placement.

Additional profiles shall be taken to retest pavement surfaces that have received corrective work and when required to check previously submitted data or to identify the limits of irregularities. Additional profiles shall be taken as prescribed below or as directed.

Curing membrane damaged during the profilograph testing or the grinding or other corrective work shall be repaired immediately at the Contractor's expense.

1. Profile intex testing of daily paving shall be performed for:

   (1) Day's paving of 1,000 linear feet or more. When a day's paving is less than 1,000 linear feet, it shall be tested with the subsequent day's production.

   (2) Each block out, bridge, and bridge approach slab - when completed and joined to previously placed and profiled pavements.

   (3) Other areas as directed.

2. Profile Index Testing. The Contractor shall notify the Engineer prior to beginning each day's profilograph operation. Horizontal and vertical calibrations shall be made by the Contractor and witnessed by the City's inspector prior to performing daily profiles. The profile index testing locations are subject to the City Engineer's approval, and testing will be witnessed by the inspector.

Profiles shall begin or end 25 linear feet from the end of pavement or from any joint between new pavement and existing pavement. Profiles shall overlap any previously profiled surfaces by at least 50 linear feet.

Profile traces shall be taken for each day's paving according to the following:

(1) For through traffic, climbing, acceleration, deceleration lanes, and ramps.

When constructed in one operation as multiple lanes with uniform lane width of 10 feet or wider: profiles shall be taken approximately three feet from and parallel to the outer edge of each exterior lane and approximately one foot right (when facing in the direction of traffic flow) of and parallel to each planned longitudinal joint or lane line.

(2) For each uniform width shoulder, lane taper or shoulder taper, a single profile shall be taken at the approximate midline.

Each profilograph shall include the following information:

(1) General Information:
- Project Number
- Project Location
- Date
- Lane Profiled
- Operator's Signature
- Inspector's Signature

(2) Each profile trace shall be marked to indicate the following:
- Beginning and Ending Stations
- Intermittent Reference Stations at Least Every 500 Feet
- Horizontal Equations Stations
- Construction Joints, Bridge Abutments
- Location on the Pavement as Required by (3) Below
- Plus Any Other Pertinent Information as Required by the Engineer

(3) Multiple profiles of a day's paving shall:

Be on the Same Width of Paper
Be Parallel to Each Other
Having Stationing Running in the Same Direction

3. Upon completion of each profilogram, the profilogram shall be immediately submitted to the City inspector. The City Engineer will review and evaluate the profilograms in accordance with Colorado Procedure 64 and report the evaluation results to the Contractor as they become available. The report will include the following for each pavement smoothness category for each class of a day's paving.

(1) Daily Average Profile Index. The daily average Profile Index is the weighted sum of all sections and partial section Profile Indexes of each category divided by the total number of 0.1 mile sections or remaining portion thereof of the daily production for that category.

(2) Section Profile Index. The section Profile Index is the average of the Profile Indexes for each 0.1 mile section or remaining portion thereof. If only one Profile Index is required, it will suffice.

(3) Irregular Areas. Irregular areas consist of those areas having high or low points in excess of that allowable in 25 feet, and areas needing reprofiling to identify the limits of irregularities.

(4) Areas and Sections Requiring Corrective Work. When the daily average Profile Index exceeds the maximum pavement surface smoothness tolerance by 20 percent, the Engineer will order paving operations suspended. Paving operations will not be allowed to resume until the Contractor has demonstrated that corrective action has been applied to the paving methods or equipment. Corrective work on pavement surfaces shall be performed in accordance with subsection 6.48.10(c).

(B) Ten-Foot Straightedge Method

The surface smoothness of pavements which are not required to be tested by the profilograph method are subject to testing by the 10-foot straightedge method.

The Contractor shall furnish an approved 10-foot straightedge and depth gauge and provide an operator to aid the Inspector in testing the finished pavement surface. Areas to be tested shall be as directed.

Areas showing high spots of more than 3/16 inch in 10 feet shall be marked and the Contractor shall perform corrective work in accordance with subsection 6.48.10(c).

(C) Corrective Work

The Contractor shall use an approved grinding device or a device consisting of multiple saws to bring the final surface within the specified pavement surface smoothness requirements. The Final surface of the concrete pavement shall provide an appearance and skid resistance comparable to adjacent sections that do not require corrective work. Additional profiles or testing may be required to define the limits of an out-of-tolerance surface variation.

Payment will not be made for any pavement that does not meet surface smoothness tolerances until corrective work has been completed and that pavement retested and found acceptable by the Engineer.

Corrective work shall be completed and accepted prior to determining pavement thickness in accordance with subsection 6.48.21 or sealing the joints in accordance with subsection 6.48.08.

6.48.11 <u>Curing</u>

Immediately after the finishing operations have been completed and as soon as marring of the concrete will not occur, the entire surface of the newly-placed concrete shall be covered and cured in accordance with the following methods. In all cases in which curing requires the use of water, the curing shall have prior right to all water supply or supplies. Failure to provide sufficient cover material or lack of water to adequately take care of both curing and other requirements shall be cause for immediate suspension of concreting operations. The concrete shall not be left exposed for more than one-half (1/2) hour between stages of curing or during the curing period.

(A) **Impervious Membrane Method:**

The entire surface of the pavement shall be sprayed uniformly with an accepted white pigmented curing compound immediately after the finishing of the surface and before the set of the concrete has taken place. Curing compound shall be applied under pressure at the rate of one (1) gallon to not more than one hundred-and-fifty (150) square feet by mechanical sprayers. The spraying equipment shall be the fully-atomizing type equipped with a tank agitator. At the time of use, the compound shall be in a thoroughly-mixed condition with the pigment uniformly dispersed throughout the vehicle. During application, the compound shall be stirred continuously by effective mechanical means. Hand-spraying of odd widths or shapes and concrete surfaces exposed by the removal of forms will be permitted. Curing compounds shall not be applied to the inside faces of joints yet to be sealed.

Membrane-curing compounds shall be wax base Protex DW3 or equal and meet the requirements of AASHTO M 148, Type 2, latest edition. Should the film become damaged from any cause within the required curing period, the damaged portions shall be repaired immediately with additional compound. Upon removal of side forms, the side of the slabs exposed shall be protected immediately to provide a curing treatment equal to that provided for the surface.

(B) **Wet Burlap Curing:**

After completion of the finishing operations, the surface of the concrete shall be entirely covered with burlap mats. The mats used shall be in such length or width that as laid they will extend at least twice the thickness of the concrete beyond the edges of the slab or structure. They shall be placed so the entire structure and all edges of the concrete, when forms are removed, are completely covered. This covering shall be placed as soon as the concrete has set sufficiently to prevent marring of the surface. After being placed, the mats shall be thoroughly saturated with water by spraying with a mist spray. The burlap shall be placed and weighted down so it remains in contact with the surface covered, and covering shall be maintained fully wetted and in position for seven (7) days after the concrete has been placed. If it becomes necessary to remove the burlap for any reason, the concrete shall not be exposed for a period of more than one-half (1/2) hour. This method of curing shall not be used when the outside air temperature is below thirty-two degrees Fahrenheit (32ºF) unless heated enclosures are provided.

(C) **Plastic Sheet Curing:**

As soon after the completion of the finishing operation as the concrete has set sufficiently to prevent marring of the surface, the top surface and sides shall be entirely covered with plastic sheet materials. The plastic sheet as prepared for use shall have dimensions such that each unit as laid will extend beyond the edges of the concrete at least twice the thickness of the concrete. The units as used shall be lapped at least twelve inches (12") and the laps of plastic sheet shall be secured in such a manner that they do not open or separate. The plastic shall be placed and weighted so it remains in contact with the surface covered during the entire curing period of seven (7) days.

(D) **Waterproof Paper Curing:**

The procedures used for plastic sheet curing shall be used when waterproof paper is used in curing concrete.

(E) **Insulation Pad:**

Insulation pads or other thermal devices may be used to protect concrete in cold weather.

(F) Other acceptable curing methods may be used upon review and acceptance by the City Engineer.

6.48.12 <u>Curing in Cold Weather</u>

When the air temperatures may be expected to fall below thirty-five degrees Fahrenheit (35ºF), the contractor's written, detailed proposal for protecting the concrete must be accepted by the City Engineer before commencement of the paving operation. A sufficient supply of straw, hay, grass, or other suitable material shall be provided along the work. The methods and materials used shall be such that a minimum temperature of forty degree Fahrenheit (40ºF) will be maintained at the surface of pavement. Acceptance of the contractor's proposed method shall not relieve the contractor of the responsibility for the quality and strength of the concrete

placed during cold weather. Any concrete damaged by frost action shall be removed and replaced at the contractor's expense.

During paving operations, day or night, when the air temperature reaches thirty-five degrees Fahrenheit (35ºF) and is falling, placement of concrete shall cease and the previously-approved protection method shall be initiated. All concrete placed within the previous seventy-two (72) hours shall be protected for a minimum of five (5) days after initial placement of the concrete.

Admixtures for curing or temperature control may be used only when permitted by the City Engineer.

6.48.13 <u>Removing Forms</u>

Unless otherwise provided, forms shall not be removed from freshly placed concrete until it has set for at least twelve (12) hours, except auxiliary forms used temporarily in widened areas. Forms shall be removed carefully to avoid damage to the pavement. After the forms have been removed, the sides of the slab shall be cured as outlined in these STANDARDS AND SPECIFICATIONS. Major honeycombed areas, as determined by the City Engineer, will be considered as defective work and shall be removed and replaced. Any area or section removed shall not be less than ten feet (10') in length nor less than full width of the lane involved. When it is necessary to remove and replace a section of pavement, any remaining portion of the slab adjacent to the joint that is less than ten feet (10') in length, shall also be removed and replaced at the contractor's expanse.

6.48.14 <u>Sealing Joints</u>

All joints shall be sealed. They shall be filled with joint sealing material before the pavement is opened to traffic, and as soon after completion of the curing period as is feasible. The sealing material shall be applied to each joint opening to conform to the details shown on the plans or as directed by the City Engineer. The pouring shall be done such that the material will not be spilled on the exposed surfaces of the concrete. Any excess material on the surface of the concrete pavement shall be removed immediately and the pavement surface cleaned. Poured joint-sealing material shall not be placed when the air temperature in the shade is less than forty degrees Fahrenheit (40ºF) unless permitted by the City Engineer.

6.48.15 <u>Cleaning and Filling Joints</u>

All concrete spanning expansion or dummy groove contraction joints shall be carefully cut away. At the end of the curing period, foreign material shall be removed from the joints by both mechanical means and the use of compressed air at ninety (90) psi pressure. All joints shall be filled flush with the specified joint filler. The joint filler shall not spill over the joint onto the adjacent surface.

6.48.16 <u>Final Seal</u>

Spray the entire concrete surface with boiled linseed oil cut back fifty percent (50%) with mineral spirits. (This is a protectionary measure against salt and abrasives during the first winter season of use.)

6.48.17 Clean-Up

When concrete operations have been completed, the contractor shall be responsible for the clean-up and removal of all leftover or waste materials resulting from any of his activities. All curbs shall be properly backfilled, and the adjacent ground left in an acceptably neat and presentable condition.

6.48.18 Concrete Pavement -- Slip-Form Method

When the pavement is to be constructed without the use of fixed forms, the following provisions shall apply:

(A) **Grade:**

After the grade has been placed and compacted to the required density designated within these specifications, the areas which will support the paving machine shall be cut to the proper elevation by means of a properly-designed machine. The grade on which the pavement is to be constructed shall then be brought to the proper profile by means of a properly-designed machine. If the density of the grade is disturbed by the grading operations, it shall be corrected by additional compaction before concrete is placed. The grade should be constructed sufficiently in advance of the placing of the concrete. If any traffic is allowed to use the prepared grade, the grade shall be checked and corrected to the satisfaction of the City Engineer immediately ahead of the placing of the concrete. Any soft spots shall be dug out to stable material and recompacted or filled with sand.

For all slip-form paving and subgrade grading operations, the contractor shall provide two string lines, one on each side of the paver or trimmer to control finished vertical grades of pavement or subgrade. Tolerance of finished grades of pavement shall not exceed one-eighth inch (1/8") transverse along a ten-foot (10') straight edge nor shall it deviate in finished elevation by more than one-half inch (1/2") from the contract plans. The contractor shall remove and replace all pavement areas not conforming to these tolerances, unless otherwise permitted by the City Engineer.

(B) **Placing and Consolidating Concrete:**

The concrete shall be placed with an approved slip-form paver designed to spread, consolidate, screed, and float-finish the freshly placed concrete in one complete pass of the machine such that a minimum of hand finish will be necessary to provide a dense and homogenous pavement in conformance with these STANDARDS AND SPECIFICATIONS.

Concrete shall be consolidated in accordance with Subsection 6.48.09. The sliding forms shall be rigidly held together laterally to prevent spreading of the forms. The concrete shall be held at a uniform consistency in accordance with the Concrete Mix P. Any inconsistent mixes delivered to the site, whether meeting the requirements of Concrete Mix P or not, which produce an unacceptable finished quality of the concrete pavement, may be rejected by the City Engineer.

The slip-form paver shall be operated with a continuous forward movement (as possible) and all operation of mixing, delivering, and spreading concrete shall be

coordinated to provide uniform progress with stopping and starting of the paver held to a minimum. If for any reason it is necessary to stop the forward movement of the paver, the vibratory and tamping elements shall also be stopped immediately. No tractive force shall be applied to the machine, except that which is controlled from the machine.

(C) **Finishing:**

The surface smoothness and texture shall meet the requirements of Subsection 6.48.09 and 6.48.10.

(D) **Curing:**

Curing shall be done in accordance with the method described in Subsection 6.48.11. The curing media shall be applied at the appropriate time and shall be applied uniformly and completely to all surfaces and edges of the pavement.

(E) **Joints:**

All joints shall be constructed in accordance with Subsection 6.48.08.

(F) **Protection Against Rain:**

In order that the concrete may be properly protected against the effects of rain before the concrete is sufficiently hardened, the contractor shall be required to have materials available at all times for the protection of the edges and surface of the unhardened concrete. Such protective materials shall consist of standard metal forms or wood plank having a nominal thickness of not less than two inches (2") and a nominal width of not less than the thickness of the pavement at its edge for the protection of the pavement edges and covering material such as burlap or cotton mats, curing paper, or plastic sheeting material for the protection of the surface of the pavement. When rain appears imminent or when requested by the City Engineer, all paving operations shall stop, forms shall be placed against the sides of pavement, and protective covering shall be placed over the surface of unhardened concrete.

6.48.19 <u>Opening to Traffic</u>

Opening to traffic, including the contractor's vehicles, shall not be permitted until the flexural strength of the concrete, as indicated by the modules of rupture of beams tested in conformity with the latest ASTM Standard Method of Test for "Flexural Strength of Concrete (Using Simple Beam With Third-Point Loading." Designation C-78 is at least five hundred (500) pounds per square inch or the compressive strength of six-inch by 12-inch (6" x 12") cylinders, tested in conformity with the latest ASTM Standard Method of Test for "Compressive Strength of Molded Concrete Cylinders." Designation C-39 is at least three thousand (3000) pounds per square inch. These tests shall be performed when the concrete is seven (7) days old unless otherwise requested by the contractor. If permanent shoulders are not in place, a six-foot (6') wide temporary earth shoulder shall be placed against the outside pavement edges before traffic is allowed on the pavement. Opening to traffic shall not constitute a final acceptance of the pavement.

6.48.20 Defects

Before final inspection and acceptance, tolerances and smoothness shall be tested by the City Engineer by means of surface-testing machine or a straightedge applied to each separate lane of pavement. All surface variations of one-eighth inch (1/8") or more in ten feet (10') shall be ground off. Brush-hammering shall not be permitted. Sections of pavement containing depressions with a depth in excess of one-eighth inch (1/8") in ten feet (10') shall be removed and replaced at the contractor's expense. Such removed sections shall not be less than full-lane width and full distance between joints in length. Slabs containing excessive cracking, fractures, spalling, or other defects shall be removed and replaced as above, when directed by the City Engineer.

6.49.00 APPURTENANT CONCRETE STRUCTURES

6.49.01 Curb and Gutter Section

The section to be constructed shall be as identified on the approved plans or as shown on the detail drawings.

6.49.02 Sidewalks

Sidewalks shall be six inches (6") thick and detached or six inches (6") thick and attached and constructed to the dimensions shown on the approved construction plans. All areas of sidewalk that will be crossed by driveways will be constructed with six-inch (6") thick concrete in residential areas and eight-inch (8") thick concrete in commercial areas.

6.49.03 Crosspans and Curb Return Fillets

Crosspans and curb return fillets shall be constructed eight inches (8") thick with six by six/ten-ten (6x6/10-10) wire mesh. Typical crosspan sections are shown on the detail drawings. Where unusual conditions prevail, additional reinforcing steel and special joints may be required by the City Engineer.

6.49.04 Curb Cuts and Driveways

Curb cuts shall be provided at all driveway locations and at additional locations, as shown on the approved plans. Construction of curb cuts shall be as shown on the detail drawings. Spacing will be as shown on the approved plans or as approved by the City Traffic Engineer.

6.49.05 Curb Ramps

Curb ramps for the handicapped shall be installed at locations designated by the City Traffic Engineer and at all intersections unless approved otherwise by the City Engineer. Curb ramps will be constructed as shown on the detail drawings.

6.49.06 Construction Stakes

The Contractor's surveyor shall provide all stakes required for curbs, gutters, walks, and structures and shall furnish all necessary information relating to lines and grades. The contractor shall be held responsible for the reasonable preservation of all such stakes. The contractor shall not remove stakes until three (3) working days after placement of concrete unless approved by the City Engineer.

6.49.07 Backfilling

When side forms are removed, the space adjoining the concrete shall be backfilled in a timely manner with suitable material properly compacted and brought flush with the surface of the concrete and adjoining ground surface. In embankments, the backfill shall be level with the top of the concrete for at least two feet (2') and then sloped to the property line. Maximum slope shall be four to one (4:1). Where detached walks occur, the space between the curb and walk shall be backfilled on a straight line from the top of walk to the top of curb.

6.49.08 Connections with Existing Concrete Curb, Gutter, and Drives

Where new construction abuts existing, the work shall be accomplished so that no abrupt change in grade between the old and new work results.

6.50.00 BRIDGES AND MAJOR DRAINAGE STRUCTURES

6.50.01 General

(A) All culvert pipe, box culverts, and bridges which will ultimately be maintained by the City of Westminster shall conform to the following:

1. AASHTO "Standard Specifications for Highway Bridges," latest edition, and applicable interims.

2. Colorado Department of Transportation’s "Standard Specifications for Road and Bridge Construction," latest edition.

3. Colorado Department of Transportation’s "Bridge Manual," Volumes I and II.

(B) All structures shall be designed to an HS-20 loading.

(C) All box culverts and bridges shall have the year of construction permanently indentured on the downstream headwall face in legible numbers. The numbers shall be three inches (3") high by one-and-one-half inches (1-1/2") deep in the headwall face.

(D) All box culvert and bridge designs shall be certified by a Professional Engineer registered in the State of Colorado who is competent to perform such designs.

6.60.00 CONSTRUCTION TRAFFIC CONTROL

6.60.01 General

Traffic control devices shall be maintained in a safe operating condition at all times. The contractor shall provide for approval by the Traffic Engineer, a traffic control plan, and shall comply with Chapter 8 of these STANDARDS AND SPECIFICATIONS. If the City Engineer finds the construction area to be inadequately barricaded, he has the authority to stop work and direct that corrective measures be taken prior to proceeding with work.

6.60.02 Pedestrian Traffic

Every precaution shall be taken to ensure that construction work does not interfere with the movement of pedestrian traffic, which shall be maintained on the sidewalk at all times. Flagmen shall be provided for guidance as necessary.

(A) Where an excavation interrupts the continuity of the sidewalk, the contractor shall provide suitable bridge or deck facilities to be supplemented by the use of such proper devices and measures as prescribed in the Manual on Uniform Traffic Control Devices, most recent edition, for the safe and uninterrupted movement of pedestrian traffic. The edges or ends of the pedestrian bridge or decking shall be beveled or chamfered to a thin edge to prevent tripping.

(B) Temporary diversion walkways shall be hard surfaced and electric lighting shall be provided and kept continuously burning during hours of darkness, when required by the City Engineer.

(C) Unless otherwise authorized by the City Engineer, pedestrians shall not be channeled to walk on the traveled portion of the roadway.

(D) Under certain conditions, it may be necessary to divert pedestrians to the sidewalk on the opposite side of the street. Such crossings shall only be made at intersections or marked pedestrian crossovers.

(E) Facilities satisfactory to the City Engineer shall be provided for pedestrian crossing at corners, pedestrian crossovers, and public transportation stops.

6.60.03 Vehicular Traffic

(A) Construction work zone traffic shall be controlled by signs, barricades, detours, etc., which are designed and installed in accordance with the Manual on Uniform Traffic Control Devices, most recent edition, and applicable City of Westminster traffic standards. Traffic control plan shall be submitted and approved by the City Engineer or his designee prior to start of any construction.

(B) During construction of new facilities, traffic control should strive to keep the motorist from entering the facility. The primary means to accomplish this is by use of temporary barricades, located in advance of the point where new construction joins existing, and by appropriate signing. New construction shall not be opened to traffic and, thus, the construction traffic control removed without the approval of the Engineering Construction Inspector and the City Traffic Engineer.

(C) In general terms, a construction traffic control plan must be drawn on a map. For minor projects or local roadways, a neat sketch of the roadways and the proposed control devices will suffice. For major projects or major roadways, the traffic control plan should be superimposed on as-builts, construction plan drawings, or other detailed map.

(D) The Manual on Uniform Traffic Control Devices shall be the basis upon which the construction traffic control plan is designed in concern with proper, prudent, and safe engineering practice. All necessary signing, striping, coning, barricading, flagging, etc. shall be shown on the plan.

(E) Directional access on roadways may be restricted [minimum travel lane width in construction area is ten feet (10')], but proper controls including flagging must be indicated. Removal of on-street parking should be considered and noted where applicable.

6.70.00 MATERIAL SPECIFICATIONS

6.71.00 SUBBASE

Subbase material shall be composed of granular material consisting, essentially, of sand, gravel, rock, slag, disintegrated granite, or a combination of such materials. The coarse portions of the material shall be sound fragments of the crushed or uncrushed materials enumerated above. Supplied material shall be a well-graded mixture containing sufficient soil mortar, crushed dust, or other proper quality binding material which, when placed and compacted in the roadway structure, will result in a firm, stable foundation. Material composed of uniform size particles, or which contains pockets of excessively fine or excessively coarse material, will not be acceptable for use.

This material need not be crushed but shall be graded within the following limits:

TABLE 6.71.00

Standard-Size of Sieve	Percent by Weight Passing Sieve
2-1/2 Inch	100
2 Inch	95 - 100
No. 4	30 - 60
No. 200	5 - 15

Liquid Limit -- 35 Maximum
Plasticity Index -- 6 Maximum

6.72.00 BASE

Base shall consist of a foundation course composed of crushed gravel or crushed stone and filler constructed on the prepared subgrade or subbase course. Materials and construction shall be in accordance with the requirements of the Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction," Section 703. Gradation shall be Class 6 (3/4-inch maximum) in accordance with the following gradation:

TABLE 6.72.00
CLASSIFICATION TABLE FOR AGGREGATE BASE COURSE

Sieve Designation	Percent by Weight Passing Square Mesh Sieve Class 6
3/4 Inch	100
No. 4	30 - 65
No. 8	25 - 55
No. 200	3 - 12

Liquid Limit -- 30 Maximum
Plasticity Index -- 6 Maximum
R-Value Minimum -- 78

6.73.00 BITUMINOUS MATERIALS

6.73.01 Prime Coat

Materials shall be in accordance with the requirements of the Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction," Section 702..

6.73.02 Hot Bituminous Pavement

All pavement shall be hot bituminous pavement of the plant mix type unless otherwise approved in writing by the City Engineer. Materials shall be in accordance with the Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction," Sections 702 and 703, and the following exceptions and/or requirements:

(A) The asphalt cement shall be Superpave Performance Graded Binders and shall conform To the requirements listed in Table 702-2 of the Colorado Department of Transportation's for Road and Bridge Constructio" (Taken from AASHTO Provisional Standard MP1) and the following:

* On arterial streets the grade of asphalt cement for the top layer shall be PG 76-28 (Polymer Modified). The bottom layers may be PG 64-22.

* On all other street classifications, the grade of asphalt cement for the top layer shall be PG 64-28 (Polymer Modified). The bottom layers may be PG 64-22.

(B) The top layer of asphalt shall be stone matrix asphalt (SMA) or hot bituminous pavement (HBP) Grading SX. The lower layers may consist of HBP Grading SG or HBP Grading S. SMA mixes will only be required as determined by the City Engineer. The minimum layer thickness shall be 2 inches and each layer should be a minimum of 2 times the aggregate size.

(C) **HBP pavements shall NOT contain any recycled or reclaimed asphalt pavements (RAP) in the mix.**

6.73.03 <u>Tack Coat</u>

When tack coat is specified on the approved plans or required by the City Engineer, all materials shall be in accordance with the requirements of the Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction," Section 702. Bituminous material shall be SS-1h emulsion.

6.73.04 <u>Seal Coat</u>

When seal coat is required, all materials shall be in accordance with the requirements of the Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction," Section 702. The type of bituminous material, cover aggregate, and rates of application will be as shown on the approved construction plans.

6.73.05 <u>Rejuvenating Agent</u>

When a rejuvenating agent is specified on the approved construction plans or required by the City Engineer, all materials shall be in accordance with the requirements of the Colorado Department of Transportation's "Standard Specifications for Road and Bridge Construction," Section 702. The rejuvenating agent shall be as shown on the approved construction plans or as specified by the City Engineer.

6.73.06 <u>Appurtenant Structures Concrete</u>

Concrete used in the construction of curb, gutter, sidewalk, drive cuts, and other appurtenant roadway concrete structures shall be in accordance with Chapter 6 of these STANDARDS AND SPECIFICATIONS.

6.74.00 STRUCTURE BACKFILL MATERIAL

Structure backfill shall comply with Colorado Department of Transportation's specifications for Class I material and meet the following requirements from laboratory sieves:

TABLE 6.74.00

Sieve Designation	Percent by Weight Passing Lab Sieve
2 Inch	100
No. 4	30 - 100
No. 50	10 - 60
No. 200	5 - 20

Flowable Fly Ash or Flowfill may be required in lieu of Class ! backfill as determined by the City Engineer.

6.75.00 PORTLAND CEMENT CONCRETE PAVEMENT -- MATERIALS

6.75.01 Concrete and Concrete Admixtures

(A) **Fine Aggregate for Concrete:**

Fine aggregate for concrete shall conform to the requirements of AASHTO M 6, latest edition. The amount of deleterious substances removable by elutriation shall not exceed three percent (3%) by dry weight of fine aggregate when tested in accordance with AASHTO T 11 unless otherwise specified. The minimum sand equivalent, as tested in accordance with AASHTO T 176 shall be eighty (80) unless otherwise specified. The fineness modules shall not be less than 2.50 nor greater than 3.50 unless otherwise approved by the City Engineer.

(B) **Coarse Aggregate for Concrete:**

Coarse aggregate for concrete shall conform to the requirement of AASHTO M 80, latest edition, except that the percentage of wear shall not exceed forty-five (45) when tested in accordance with AASHTO T 96. Coarse aggregate shall conform to the grading in Table 6.75.01 for the grading specified in Table 6.77.04. Sizes 357 and 467 shall each be furnished in two separate sizes and combined in the plant in the proportions necessary to conform to the grading requirements. Size 357 is a combination of No. 3 and No. 57, and Size No. 467 is a combination of No. 4 and No. 67.

(C) **Portland Cement:**

Portland cement shall conform to the requirements of the following specifications for the type specified or permitted:

Type	Specifications
Portland Cement -- Types I, II, and III	ASTM C 150 AASHTO M 85
Air-Entraining Portland Cement	AASHTO M 134
Masonry Cement	AASHTO M 150

In general, Type II cement shall be used in concrete which will be in contact with the soil, unless otherwise allowed or directed by the City Engineer. Unless otherwise permitted by the City Engineer, the product of only one mill of any one brand and type of Portland cement shall be used on the project, except for reduction of any excessive air entrainment where air-entrainment cement is used. The contractor shall provide suitable means of storing and protecting the cement against dampness. Cement which for any reason has become partially set or which contains lumps of caked cement shall be rejected. Cement salvaged from discarded or used bags shall not be used.

TABLE 6.75.01
Concrete Aggregate Gradation Table
Percentages Passing Designated Sieves and Nominal Size Designation

	Coarse Aggregates (From AASHTO M 43)					Fine Aggregate				
	* No.3	* No.4	No.6	No.7	No.8	* No.57	* No.67	** No.357	** No.467	AASHTO M 6
Sieve Size	2" to1"	1-1/2" to3/4"	3/4" to3/8"	1/2" to#4	3/8" to#8	1" to#4	3/4" to#4	2" to#4	1-1/2" to#4	#4 to#100
2-1/2	100	.....	.....	.....	.....	.....	.....	.....	100	.....
2"	90-100	100	.....	.....	.....	.....	.....	.....	95-100	100
1-1/2"	35-70	90-100	.....	.....	.....	100	.....	.....	.....	95-100
1"	0-15	20-55	100	.....	.....	95-100	100	35-70	.....	.....
3/4"	.....	0-15	90-100	100	.....	.....	90-100	.....	35-70	.....
1/2"	0-5	.....	20-55	90-100	100	25-60	.....	10-30	.....	.....
3/8"	.....	0-5	0-15	40-70	85-100	.....	20-55	.....	10-30	100
#4	.....	.....	0-5	0-15	10-30	0-10	0-10	0-5	0-5	95-100
#8	.....	.....	.....	0-5	0-10	0-5	0-5	.....	.....	.....
#16	.....	.....	.....	.....	0-5	.....	.....	.....	.....	45-80
#50	.....	.....	.....	.....	.....	.....	.....	.....	.....	10-30
#100	.....	.....	.....	.....	.....	.....	.....	.....	.....	2-10

* Additional primary gradings may be permitted when produced on the project provided the theoretical combination meets the specifications for combined aggregate sizes. Size No. 357 is a combination of No. 3 and No. 57. Size No. 467 is a combination of No. 4 and No.67

6.75.02 <u>Forms</u>

Straight side forms shall be made of a metal having a thickness of not less than seven-thirty-seconds of an inch (7/32") and shall be furnished in sections not less than ten feet (10') in length. Forms shall have a depth equal to the prescribed edge thickness of the concrete, without horizontal joint, and a base width equal to or greater than the depth of the forms. Flexible or curved forms of proper radius shall be used for curves of one-hundred-foot (100') radius or less. Flexible or curved forms shall be of a design acceptable to the City Engineer. Forms shall be provided with adequate devices for secure setting so when in place they will withstand, without visible spring or settlement, the impact and vibration of the consolidating and finishing equipment. Flange braces shall extend outward on the base not less an two-thirds (2/3) the height of the form. Forms with battered top surfaces and bent, twisted, or broken forms shall be removed from the site. Repaired forms shall not be used until accepted by the City Engineer. Built-up forms shall not be used except where the total area of pavement of any specified thickness on the project is less than two thousand (2000) square yards. The top face of the form shall not vary from a true plane more than one-eighth inch (1/8") in ten feet (10'), and the upstanding leg shall not vary more than one-quarter inch (1/4"). The forms shall contain provisions for locking the ends of abutting form sections together tightly and for secure setting.

Forms for bridge approach slabs or for pavement areas with irregular dimensions shall be made of metal or straight, sound timber. Forms shall be free from warp and of sufficient strength to resist springing out of shape. Forms shall be staked securely to line and grade to the satisfaction of the City Engineer. All mortar and dirt shall be removed from the forms that have been previously used.

6.75.03 <u>Reinforcing Steel</u>

Reinforcing steel shall conform to the requirements of the following specifications:

(A) Deformed and plain billet -- steel bars for concrete reinforcement -- AASHTO M 31

(B) Axle-steel deformed and plain bars for concrete reinforcement -- AASHTO M 53

(C) Fabricated steel bar or rod mats for concrete reinforcement

(D) Welded steel wire fabric for concrete reinforcement -- AASHTO M 55

Bars conforming to AASHTO M 31 and M 53 shall be furnished in Grade 60 for No. 5 bars and larger and Grade 40 or Grade 60 for smaller than No. 5. Reinforcing mesh shall be 6 x 6 - W2.9 x W2.9 with a weight of at least forty-one (41) pounds per one hundred (100) square feet.

6.75.04 Water

Water used in mixing or curing shall be clean and free of oil, salt, acid alkali, sugar, vegetable, or other substance injurious to the finished product. Water will be tested in accordance with, and shall meet, the suggested requirements of AASHTO T 26, latest edition. Water known to be of potable quality may be used without test. Where the source of water is relatively shallow, the intake shall be so enclosed as to exclude silt, mud, grass, or other foreign materials.

6.75.05 Joints

(A) **Joint Sealing Compound:**

Material for filling all types of pavement joints shall be a hot-poured elastomeric-type sealant specifically manufactured for sealing joints in concrete. The material shall not crack or break its bond when exposed to a temperature of zero degrees Fahrenheit (0°F). Joint sealing compounds shall meet the requirements of ASTM D 3406.

(B) **Expansion Joints:**

Expansion joint material shall be non-extruding and resilient bituminous types and shall conform to AASHTO M 213. The filler shall be furnished in a single piece for the depth and thickness required for the joint.

(C) **Cold Joint Sealer:**

Cold-applied joint sealer material for concrete slab joints shall conform to the requirements of ASTM D 1850, latest edition, "Concrete Joint Sealer, Cold Application Type." Cold-applied joint sealer shall be of such character that a homogenous mix can be obtained by combining the separate substances, either mechanically or manually, without having to heat the blended material above a temperature of one-hundred degrees Fahrenheit (100°F). The material shall pour or extrude readily at a temperature of seventy degrees Fahrenheit (70°F) immediately after preparation for use and shall remain in a condition suitable for application for at least one (1) hour.

6.75.06 Metal Supports

(A) **Steel Spaces:**

Metal chairs used to support longitudinal, tie, or reinforcing bar shall be channel shaped, pressed out of sheet steel of not less than twelve (12) gauge (U.S. Standard) metal.

(B) **Dowel Baskets:**

Pre-formed, continuous dowel expansion joint material supports shall be eighteen (18) gauge (U.S. Standard) metal or three- (3) gauge wire chairs with ten- (10) gauge tie wires or heavier spaced no further than eighteen inches (18") along the axis of the expansion joint.

6.75.07 Expansion Tubes

Metal dowel caps or tubes shall be manufactured from thirty-two- (32) gauge sheet metal or heavier, shall not be less than five inches (5") in length, shall be indented to provide a limiting stop for the dowel bars, and shall provide unobstructed expansion space of not less than one inch (1") to permit movement of the dowel bar. The inside diameter shall be one-sixteenth inch (1/16") larger than the diameter of the specified dowel bars and the closed end shall be watertight. Caps made from bituminous-treated paper or other similar material shall not be used.

6.75.08 Form Oil

Commercial quality, colorless mineral oil, free of kerosene and of a suitable viscosity, shall be used as form oil.

6.75.09 Air-Entraining Admixtures

Air-entraining admixtures shall conform to the requirements of AASHTO M 154, latest edition, and ASTM C 260, latest edition. Admixtures which have been frozen will be rejected.

6.75.10 Curing Materials

Curing materials shall conform to the following requirements:

Burlap cloth made from Jute or Keaff	AASHTO M 182
Sheet materials for curing concrete	AASHTO M 171
Liquid membrame-forming compounds for curing concrete (white pigmented) Type 2, latest edition	AASHTO M 148

Straw used for curing shall consist of threshed straw or oats, barley, wheat, or rye. Clean field or marsh hay may be substituted when approved by the City Engineer. Old, dry straw or hay which breaks readily in the spreading process will not be permitted.

6.75.11 Chemical Admixtures

Chemical admixtures, if permitted by the City Engineer for concrete, shall conform to the requirements of AASHTO M 194, latest edition. Admixtures which have been frozen will be rejected.

6.75.12 Epoxy

Epoxy used for bonding new or wet concrete to old concrete shall be an acceptable product and shall be of the type specifically intended for bonding wet concrete to existing concrete and shall be submitted to the City Engineer for review prior to use.

6.75.13 Fly Ash

Fly ash for concrete, when permitted by the City Engineer, shall conform to the requirements of ASTM C 618, Table 1-A, latest edition, for Class C or Class F. (The pozzolanic activity index shall be 85 for Class C and Class F, Fly Ash.) Class C fly ash will not be permitted where sulfate-resistant cement is required.

The contractor shall notify the City Engineer of the source of fly ash for review before using in the project. The fly ash shall be subject to sampling and testing by agents of the City. Test results that do not meet the physical and chemical requirements may result in the suspension of the use of fly ash until the necessary corrections have been taken to ensure that the material meets specifications. All costs associated with possible testing of fly ash by the City, which do not meet these specifications, shall be paid by the contractor. The fly ash for use on the project shall have been tested by the contractor for compliance with these specifications and submitted to the City Engineer for review prior to its use in the project.

6.75.14 Test Specimens

The contractor shall furnish the concrete necessary for casting test cylinders. The number of cylinders and tests shall be as follows:

CONCRETE PAVEMENT

Type of Test	Frequency
Gradation (aggregate)	1 per 2500 sq. yard or fraction thereof for each size aggregate
Moisture Content, fine aggregate	1 per day or as often as needed for quality control
Moisture Content, coarse aggregate	1 per day minimum where moisture content is +0.5 percent from SSD condition
Slump	1 per set of cylinders and as often as needed for quality control
Air Content	1 per set of cylinders and as often as needed for quality control
Yield and Cement Factor	1 per set of cylinders and as often as needed for quality control
Compressive Strength	1 set of four (4) cylinders per 5000 sq. yards or major fraction thereof on each day pavement is placed, with two (2) cylinders to be field-cured. One additional set shall be made if the contractor intends to open early for traffic in accordance with Section 6.48.19
Thickness	1 per 1250 linear feet each traffic lane on freshly finished concrete and as often as needed for quality control

The degree and frequencies of all concrete testing beyond normal specified frequencies, if necessary to assure quality control, shall be determined by the City Engineer at the time of concrete construction. All concrete testing necessary beyond normal specified frequencies to assure quality control shall be paid for by the contractor.

6.76.00 PORTLAND CEMENT CONCRETE PAVEMENT -- EQUIPMENT

6.76.01 General

All equipment necessary for the proper preparation of the subgrade, placing, finishing, and curing of the concrete pavement shall be on the project in good working condition and shall have been inspected by the City Engineer before the contractor will be permitted to begin paving operations. Throughout construction, the contractor shall maintain sufficient, adequate equipment to assure the proper execution of the work.

6.76.02 Roller

Final subgrade compaction shall be by means of a self-propelled roller having a weight on the rear wheels of the roller of not less than two-hundred-and-fifty (250) pounds per inch of tread. Vibratory rollers may be used with the permission of the City Engineer. The use of rubber-tired rollers is encouraged.

6.76.03 Subgrade Planer

The subgrade planer shall have an adjustable cutting edge which shall be set to leave the subgrade at the elevation necessary to produce pavement of the thickness shown on the plans. Each end of the planer shall be supported on the forms by means of two rollers with sufficient spacing to maintain stability. The planer shall be of sufficient weight to maintain contact with the forms during planing operations. Wheels or rollers on previously-placed concrete shall be rubber-faced and shall be adjusted so that bearing on concrete shall not be less than three inches (3") from the edge of a pavement.

6.76.04 Forms

(A) Side forms shall be made of metal except on curves of less than a one-hundred-foot (100') radius where wooden forms may be used. Forms shall have base width of not less than eight inches (8") for all forms more than eight inches (8") in height. All side forms less than eight inches (8") in height shall have a base width of not less than six inches (6"). The minimum length of each section of form used shall be ten feet (10'). Each section of form shall be straight and free from bends or warps.

(B) The maximum deviation of the top surface of any section shall not exceed one-eighth inch (1/8"). The inside face shall not deviate more than one-fourth inch (1/4") from a straight line. The method of connection between sections shall be such that the joint thus formed shall be free from movement in any direction. Forms shall be of such cross-section and strength and so secured as to resist the pressure of the concrete when placed and the impact and vibration of any equipment which they support without springing or settlement.

(C) Each ten-foot (10') length of form shall have at least three (3) form braces and pin sockets which shall be spaced at intervals of not more than five feet (5'), having the end brace and socket not less than six inches (6") from the end of the form.

(D) Forms that are not required to support a mechanical finishing machine, subgrade planer, or other similar heavy equipment may, upon approval of the City Engineer, be made of wood. They shall have sufficient stiffness and be so staked to remain vertical and true to lines and grade during the placing and finishing of the concrete. Straight wood forms shall have a thickness of not less than one-and-one-half inches (1-1/2"). Wood forms used at intersection radius points may be one-fourth inch (1/4") thick. All wood forms shall be dressed on the side supporting the concrete and on their upper edge.

(E) Curb forms, if used, shall be made of steel, except where returns of small radius or other special sections make the use of steel forms impractical. Back forms for curbs shall be rigidly attached to the side forms for the pavement slab using all the fastening provided by the manufacturer of the forms. Slip forms or curb mules may be used.

6.76.05 <u>Vibrators</u>

Vibratory units shall be capable of frequencies of not less than ten thousand (10,000) vibrations per minute in air and shall produce vibration in vertical and horizontal planes and ensure a downward vibration of an intensity as great as in other directions to provide thorough vibration through the full depth of the concrete. The unit shall be adjustable to approximately the cross-section of the finished surface. Vibration shall not be used as a means to cause concrete to flow or run into position in lieu of placing and shall not be prolonged to the point where segregation occurs.

6.76.06 <u>Finishing Equipment</u>

(A) A screed or template shall be used to roughly strike off the first layer of concrete to permit placing of required reinforcement in the specified position.

(B) The contractor shall furnish an approved mechanical finishing machine of the screeding and troweling type. It shall be designed and operated both to strike off and to consolidate. The finishing machine shall be of adequate strength to withstand severe use and shall be fully and accurately adjustable to make the pavement conform to the required cross-section shown on the plans. If it is necessary to operate one or both sets of wheels on previously-placed concrete, they shall be rubber-faced and shall be adjusted so that bearing on concrete will not be less than three inches (3") from the edge of the pavement.

(C) Such additional hand equipment -- including but not limited to wooden floats, straightedges, bridges, edgers, etc. required for proper finishing -- shall be furnished by the contractor.

6.76.07 Concrete Saw

When sawing joints, the contractor shall provide sawing equipment adequate in number of units and power to complete the sawing with a water-cooled diamond-edge saw blade or an abrasive wheel to the required dimensions and at the required rate. The contractor shall provide at least one stand-by saw in good working order and meeting the same requirements as stated above. An ample supply of saw blades shall be maintained at the site of the work at all times during sawing operations. The contractor shall provide adequate artificial lighting facilities for night sawing. All of this equipment shall be on the job both before and continuously during concrete placement.

6.77.00 PORTLAND CEMENT CONCRETE PAVING -- MIXING

6.77.01 General Mixing

Concrete may be mixed in a central mix plant, or in truck mixers. The mixer shall be of an approved type and capacity. Mixing time shall be measured from the time all materials, except water, are placed in the drum.

The time elapsing from the time water is added to the mix (or cement comes in contact with aggregate) until the concrete is deposited in place at the site of the work shall not exceed forty-five (45) minutes when the concrete is hauled in non-agitating trucks nor ninety (90) minutes when hauled in truck mixers or agitating trucks. The contractor may use approved mixes utilizing admixtures which conform to AASHTO M 194, latest edition, Types A, B, and D. The use of AASHTO M 194 admixtures Types C and E may be used only when specifically provided for in the contract or upon written permission from the City Engineer.

6.77.02 Stationary Mixing

When mixing or in a central mixing plant, the mixing time shall not be less than fifty (50) seconds nor more than ninety (90) seconds. Four (4) seconds shall be added to the specified mixing time if timing starts the instant the skip reaches its maximum raised position. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

The volume of concrete mixed per batch may exceed the mixer's nominal capacity in cubic feet, as shown on the manufacturer's standard rating plate on the mixer, up to ten percent (10%) provided concrete test data for strength, segregation, and uniform consistency are satisfactory and provided spillage of concrete does not occur.

The batch shall be charged into the drum such that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform and all water shall be in the drum by the end of the first fifteen (15) seconds of the mixing period. The throat of the drum shall be kept free of accumulations that may restrict the free flow of materials into the drum.

The timing device on stationary mixers shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure

of the timing device, the contractor will be permitted to operate while it is being repaired, provided he furnishes an approved timepiece equipped with minute and second hands. If the timing device is not placed in good working order within twenty-four (24) hours, further use of the mixer will be prohibited until repairs are made.

6.77.03 Ready-Mixed Concrete

The use of ready-mixed concrete in no way relieves the contractor or developer of the responsibility for proportion, mix, delivery, or placement of concrete. All concrete must conform to all requirements of these STANDARDS AND SPECIFICATIONS and ASTM C-94 and AASHTO M 157.

The City shall have free access to the mixing plant at all times. The organization supplying the concrete shall have sufficient plant and transportation facilities to assure continuous delivery of the concrete at the required rate. (The contractor will collect delivery, or batch, tickets from the driver for all concrete used on the project and deliver them to the City Engineer.) Batch tickets shall provide the following information:

(A) Weight and type of cement

(B) Weights of fine and coarse aggregates

(C) Volume (in gallons) of water, including surface water on aggregates

(D) Quantity (cubic yards) per batch

(E) Times of batching and discharging of concrete

(F) Name of batch plant

(G) Name of contractor

(H) Type of mixture (mix designations code)

(I) Name and amount of admixture

(J) Date and truck number

6.77.04 Mixing Proportions of Concrete Materials

Proportioning shall conform to the requirements for Class P concrete as described in Table 6.77.04. When small quantities of pavement are involved (1000 square feet or less), Class A, AX, or B may be used in lieu of Class P upon approval of the City Engineer. The design mixes are described in Table 6.77.04.

Upon review by the City Engineer, the contractor shall have the option of substituting approved fly ash for Portland cement in any class concrete mentioned above up to a maximum of twenty percent (20%) by weight. The total weight of cement plus fly ash shall not be less than the minimum weight for cement content as shown in Table 6.77.04. Where the voluntary use of fly ash by the contractor results in delays, necessary changes in admixture quantities or admixture source, or unsatisfactory work, the costs of such delays, changes, or corrective actions shall be borne by the contractor. In the event the finished concrete is unsuitable for its intended purpose, the use of fly ash shall be discontinued.

TABLE 6.77.04
Concrete Table

	Concrete Class	A	AX	B	(k)P
LABORATORY	DESIGN MINIMUM [a] COMPRESSIVE STRENGTH 28 days (45 days for Type V cement) Pounds Per Square Inch	3750	3750	3750	3750
	CEMENT CONTENT (Cement Factor) Range (Pounds Per Cubic Yard):				
	Minimum --	550	600	550	550
	Maximum --	600	700	600	600
	WATER CEMENT RATIO (Pounds of Water Per Pounds of Cement):	0.500	0.500	0.530	0.480
	PERCENT ENTRAINED & ENTRAPPED AIR (Total Range):	4-7	5-8	5-8	4-7
COARSE	CONSISTENCY AASHTO DESIGNATION T-119 [b] -- Range in Inches:	2-4	1-3	1-4	1-3
	AGGREGATE AASHTO DESIGNATION M-43 -- Size Number:	467	(f)	67	467 357
FINE	AGGREGATE AASHTO DESIGNATION M-6 -- Percent Total Aggregate Range:	34-39	(f)	37-44	34-38 33-38

[a] Not a field specification requirement. The desired minimum field strength is 80 percent of the specified laboratory strength.

[b] The point of acceptance for consistency requirements will be at the mixer discharge for transit-mixed concrete.

6.77.05 Limitations of Mixing

Concrete shall be mixed, placed, and finished only when the natural light is sufficient unless an adequate and approved artificial lighting system is provided. Unless authorized in writing by the City Engineer, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches forty degrees Fahrenheit (40ºF) and not resumed until an ascending air temperature in the shade and away from artificial heat reaches thirty-five degrees Fahrenheit (35ºF).

When concreting is authorized during cold weather, the aggregates may be heated by either steam or dry heat prior to being placed in the mixer. The apparatus used shall heat the mass uniformly and shall be arranged to preclude the possible occurrence of overheated areas which might injure the materials. Unless otherwise authorized by the City Engineer, the temperature of the mixed concrete shall not be less than fifty degrees Fahrenheit (50ºF) and not more than eighty degrees Fahrenheit (80ºF) at the time of placing it in the forms.

If the air temperature is thirty-five degrees Fahrenheit (35ºF) or less at the time of placing concrete, it will be required that the water and/or the aggregate be heated to not less than seventy degree Fahrenheit (70ºF) nor more than one-hundred-fifty degrees Fahrenheit (150ºF). Concrete shall not be placed on frozen subgrade nor shall frozen aggregates be used in the concrete. In concreting operations during the summer months, maximum temperature of the mixed concrete shall not exceed ninety degrees Fahrenheit (90ºF).

In cold weather, aggregates and water may be heated as part of the batching operation but they shall not be heated beyond a temperature of one-hundred-fifty degrees Fahrenheit (150ºF). Aggregates shall not be heated directly by gas or oil flame or on sheet metal over direct flame. Materials containing frost or lumps of frozen material shall not be used in the mix, and their presence in the concrete shall be cause for rejection of that batch.