Curb & Gutter Manual

This manual was reviewed and endorsed by the American Concrete Pavement Association. The manual was also approved by the NRMCA's Research Engineering and Standards Committee, Task Group on Pavements. Please send comments or suggestions to National Ready Mixed Concrete Association c/o Manager of Applied Engineering at 900 Spring Street, Silver Spring, Maryland, 20910 or via the Internet at www.nrmca.org.

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Curbs reduce the amount of space or right-of-way required for a street by eliminating drainage swales and their flat side slopes; curbs also reduce the lengths of driveways built from streets to homes or businesses. In some jurisdictions where both curbed and uncurbed streets are allowed by subdivision ordinances, streets with curbed sections require less dedicated right-of-way than streets without curbs, for example 50 ft for local streets with curbs, or 60 ft for local streets without curbs. The elimination of drainage swales also reduces maintenance by eliminating the cleaning of ditches, the mowing of ditch banks, and the care of culverts and their end sections that carry water under driveways.

Light reflective surfaces of concrete curbs delineate pavement edges and improve visibility for drivers at night, thus promoting safety. Where there are no concrete curbs to outline the edges of roads and streets, it is now common practice to mark the pavement edges with stripes of white paint.

Curbs improve the efficiency of street sweepers by concentrating debris for easy, mechanical pickup, as opposed to having it scattered along shoulders and drainage swales where it must be picked up by hand.

Concrete curbs have the integrity to withstand the impacts of snowplows.

A comparison of pavement sections with curbs and without curbs is shown in Figure I illustrating the advantages in land use provided by concrete curbs. It should be noted that most of the advantages listed above pertain only to concrete curbs or concrete curbs and gutters that extend down to the bottom of pavements. Adding asphalt curbs along the edges of asphalt pavements cannot provide the confinement to improve compaction or other long-term benefits.

3. **Types of Curbs**

Concrete curbs are generally classified as barrier curbs or mountable curbs. Either type can be constructed in many different shapes, depending on regional preferences, purposes and construction costs. Typical cross sections of the most commonly used curbs and curb and gutter sections are shown in Figure II. Barrier curbs, also known as straight curbs, resemble the stone slabs used originally for curbs and form abrupt obstacles to vehicles leaving pavements.

Mountable curbs, sometimes referred to as roll curbs, have sloping faces that allow vehicles to encroach on them without damaging tires and wheels; and if the slopes are gentle enough, cars can cross them to access driveways. Curbs that cannot be crossed without damage or discomfort must have sections where the heights of the curbs are reduced for vehicular entrances. The low portions are usually referred to as depressed curbs. When curbs are constructed in areas where buildings have already been erected and driveways established, the depressed portions can be easily designated, but in developing areas where the driveways have not been located, mountable curbs are usually
preferred.

Either type of curb can have an apron or gutter section attached and become a combined curb and gutter. Combined curb and gutter sections are commonly used along streets and parking lots in urban areas, especially with asphalt pavements, to provide the advantages of stable concrete gutters with sustainable flow lines along the curbs.

Because concrete can be readily shaped to transition between cross-sections, curbs can be tapered to meet ramps for pedestrian crossings where these are preferred or to meet requirements for the disabled.

Curbs built monolithically with concrete pavements project above the pavement at the edges. These are referred to as monolithic curbs or integral curbs, as opposed to separate curbs. As the edges of concrete pavements with the added thickness of curbs are stronger and stiffer, deflections caused by heavy wheels close to the outside edges are reduced. Where curbs are cast on hardened concrete slabs, resulting in cold joints between the curbs and slabs, there are opportunities for planes of weakness and water penetration, which can result in shortened service life.

A separate curb and gutter must be tied to the pavement slab with deformed steel bars if there is to be effective load transfer. If a curb is separate from the pavement the joint between the pavement and the curb may require maintenance.

4. **Requirements for Curbs**

Curbs must meet several basic requirements if they are to serve their intended purposes and have long service life. Curbs must have the required mass, stability and strength to withstand the impacts of traffic and the effects of their environments and to maintain their positions even when crossed by traffic or struck by snowplows. They must have the strength to bridge small areas where subgrade support is inadequate. Designing curb sections to have adequate stability is discussed below in Section 5.0.

The standard sections shown in Figure II have been proven to have the necessary mass for strength and stability. Separate curb and gutter sections should be at least two feet wide with greater widths having more stability for a relatively small amount of construction costs.

In severe environments, curbs must have adequate durability to resist freeze-thaw cycles while being buried in snow and ice plowed to the sides of streets and being saturated with brine from deicing salts that is carried to the sides. The requirements for durable concrete that will withstand these severe conditions are discussed in Section 9.0.
Another important requirement is visibility. Because of their light and reflective surfaces, concrete curbs can be easily seen, even at night when pavements are wet. The washings of rain and the removal of debris by street sweeping are sufficient to meet this requirement.

5. Curb Design

The design of curbs is more dependent on successful experience and regional preferences, and less on rigorous analyses compared to the design of other concrete structures. The review of a few available publications on concrete curbs reveals what types have been used but there is no specification regarding the forces acting on curbs or calculations on reducing stresses to acceptable limits. This is because experience has shown that curb sections proportioned to have adequate mass to provide the required stability are unlikely to fail from any imposed loads or impacts. Like other concrete members, curbs should be jointed or reinforced to accommodate the effects of volume changes due to shrinkage, temperature, or moisture changes. Jointing and reinforcing are discussed in Section 7.0.

Besides meeting the basic requirements discussed above, good curb design should allow economical and efficient construction. Economical construction results from designs that reduce labor, permit the use of any of the efficient curb forming machines available today, and take advantage of standardized cross sections that provide the necessary properties. Minor variations in shapes or dimensions that add nothing to the strength or utility should be avoided. Templates or "mules" can be manufactured for any desired cross-sections form curb shapes, but they are costly. If the entire cost of a special mule must be amortized on a single project, the cost of the curb must necessarily be increased to cover that expense, even though the utility of the curb is not increased over that of a similar standard section.

6. AASHTO Standards

Cross sections of typical curbs of the most common types are shown in Figure II. These are as shown in A Policy on Geometric Design of Highways and Streets, 1990, published by the American Association of State Highway and Transportation Officials (AASHTO). Identical cross sections with soft metric conversion are found in the 1994 edition of this publication. The use of one of these cross sections is recommended.

These curbs can be constructed with conventional forms or with slipform equipment. Note that the faces of the curbs have slight slopes or batter to facilitate slipform construction or to ease the removal of conventional forms sooner, without objectionable slumping of the sides. The batter also allows soil compaction equipment to operate next to the curbs with less likelihood of damaging them, and to provide better compaction.
7. Joints

Concrete curbs will experience shrinkage, temperature, or moisture changes. They will crack when the built up stresses due to these factors exceed the concrete tensile strength unless adequate measures are taken, for example adequate jointing.

Good jointing practice will anticipate these cracks and locate them in acceptable locations. When a curb is constructed as part of a pavement, or tied to a pavement, the jointing pattern for the pavement should be carried through the curb. Separate curbs should be jointed at intervals close enough to preclude the formation of intermediate cracks. Some designers prefer to space joints at long intervals and call for reinforcing steel properly located and supported in the concrete to tie the concrete together after it cracks. Including reinforcing steel complicates construction and increases cost. In general, joint spacing will be proportional to the mass of the curb section, and successful local experience should determine joint spacing. Usually contraction joint spacing of fifteen feet (15 ft) is necessary to avoid intermediate cracks in separate curbs.

Whether or not joints should be spaced close enough to control all cracking is a matter of local preference. Small cracks through curbs do not usually reduce the serviceability or attractiveness of curbs, as long as the curbs are uniformly supported.

The depth of contraction joints should be one-fourth of the cross section of the concrete. These joints can be sawed, hand-formed, or formed with thin steel division plates. Sawing must be done as soon as possible without raveling the edges of the joints, before cracks form. Joints can be formed by using jointing tools of the proper shape, or by impressing tee-bars shaped to match the cross section of the curb and gutter. Division plates are placed in the forms and then removed after the concrete has set.

Joints and cracks in concrete curbs do not have to be sealed. The cost would by far exceed any benefits. If a street is maintained with a joint cleaning and sealing program, the longitudinal joint between street and curb apron should be sealed unless the two elements are closely tied together.

Curbs and concrete sidewalks are sometimes built adjacent to each other in areas of limited right-of-way, in commercial areas, or next to parking lots. Where there are attempts to combine relatively thin sidewalks with heavier curb sections, it is usually best to separate the two elements of different thickness by isolation joints. If they are not separated an effective contraction joint or steel reinforcement should be provided to tie across the locations of anticipated cracks. Where there are safety sidewalks along sides of roadways in tunnels, there is usually structural reinforcing in the curbs and sidewalks to make the normal contraction joints unnecessary.

Curbs at street intersections and some driveway entrances make sharp curves that affect the ways curbs move. The usual practice is to provide isolation or expansion joints at the tangent points.
in separate curbs or to locate contraction joints through curbs and pavements where integral curbs are used. Driveway entrances with curved concrete aprons should be separated from adjoining curbs with isolation joints at the tangent points. Isolation joints should also separate ramps for pedestrians at intersection corners from curbs. If isolation joints are needed in unsymmetrical street intersections, the isolation joints should also be carried through abutting curbs. Isolation joints should be formed by single pieces of joint material that extend for the full depths and widths of the joints so that no concrete in the joint spaces interferes with the movement of the concrete on either side. In slipform curbs, the materials can be installed after concrete is removed by sawing or raking partially set concrete to open slots just wide enough for snug fits of jointing materials.

8. Drainage

For combined curb and gutter sections, the aprons (the portions between pavements and the faces of the curbs) should have adequate hydraulic capacity to carry runoff from most rainstorms. Making aprons wider reduces the opportunity for rainwater to move down through joints between curbs and pavements. Wider aprons may also discourage drivers from driving close to curbs.

Since one important function of curbs is to collect runoff, provisions must be made periodically to drain water away before the roadways are flooded. In areas where there are storm sewers, the flow in gutters is diverted through inlets built into the curbs and/or gutters. In semi-arid regions where rains are infrequent, inlets are sometimes only gaps in curbs through which water can exit. In most other places, inlets are fitted with iron castings designed to match the shapes of the curbs (another good reason for using standard shapes), and with grates that extend one or two feet into the gutters. The spacing of inlets depends on the amounts of water that must be handled, and are calculated to avoid flooding of streets or roadways except on infrequent occasions, such as once every ten or twenty years. While inlet locations must be governed by rainfall and pavement elevations, designers should consider their effects on curb jointing. Inlets, which are more or less anchored in place, should be isolated from curbs and gutters.

Because the sides of streets adjacent to curbs are often used by bicyclists, it is important that grates in the aprons of curbs have openings that will not be safety hazards to bicycle wheels. Grates are available that allow for the safe passage of bicycles.

9. Concrete and Other Materials

Specifications should call for concrete meeting the requirements of the local transportation agency or ASTM C 94, with appropriate qualifications for strength, aggregate size, slump, and entrained air. ASTM C 94 covers concrete manufacturing, delivery, and quality control. By reference, ASTM C 94 incorporates the ASTM standards for concrete ingredients and quality control
tests. Ordering concrete produced by a plant currently certified by the NRMCA Ready Mixed Plant Certification Program can provide assurance that the supplier is capable of producing and delivering quality concrete. ACI 211.1, “Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete” can be useful in selecting concrete mixture proportions. The use of standard specifications of the local transportation agency can be advantageous where materials suppliers are familiar with them and routinely deliver quality concrete to meet them.

In areas with mild exposure, specifications may require concrete with a 28-day compressive strength of only 3,000 psi or the concrete quality may be dictated by proportioning to allow efficient slipforming without slumping. Slipforming necessarily limits the amount of water that can be used in mix and the slipform process requires cementitious materials and aggregate combinations that will produce smooth surfaces without handwork for closing voids.

In areas with severe exposure, specifications may require a 28-day compressive strength of at least 4,500 psi for durability. The concrete must be air entrained and have a high quality cementitious paste to survive many freeze-thaw cycles and applications of deicer salts. It should have at least 5% entrained air, with a maximum allowable of 8%. Some designers consider 4,000 psi concrete to have adequate durability for exterior use, but a higher requirement for 28-day compressive strength is suggested because of the extremely harsh conditions curbs must endure. Local availability and construction methods will determine top size coarse aggregate, but 3/4 in. top size is commonly used. Smaller coarse aggregates will require additional water in concrete and should be avoided if possible. Required consistency of the concrete will depend on construction methods. Whether shaped by hand or by slipform machine, the concrete may have to stand by itself, and therefore high slumps are not acceptable. In any case, concrete should be placed with the lowest amount of water that will provide workability and finishability. Proper combined aggregate gradations are important to achieve workability with lower water contents that enhance strength and durability.

The severity of exposure is defined in ACI 211.1. Concrete is in mild exposure area if the concrete is not exposed to freezing or to deicing salts. Concrete is air entrained to improve workability rather than durability. Concrete is in moderate exposure area if freezing temperatures are expected but the concrete will not be saturated for extended periods prior to freezing, and will not be exposed to deicing salts. Concrete is in severe exposure area if concrete will be exposed to deicing salts, or where concrete will be in contact with water and will potentially be saturated prior to freezing.

Silica fume, an extremely fine pozzolan that reduces permeability and increases strength, fly ash or slag are becoming popular constituents of concrete that must be durable in extremely harsh situations.

Reinforcing steel used as tie bars or longitudinal reinforcing should comply with ASTM A615.
Membrane forming curing compounds should comply with ASTM C 309 and isolation joint material should meet ASTM D 994, D 1751, or D 1752.

10. Curb Construction

Like concrete pavements, curbs are constructed with traditional forms or slipform equipment, separately or along with the construction of concrete pavements. The procedures for efficient and economical construction of concrete curbs are practically parallel to those for concrete streets and roads. These include the preparation of the subgrade to provide uniform support, the accurate alignment of forms or slipform equipment, the placing and consolidating of durable concrete, jointing for crack control, finishing and texturing, curing, and protecting until ready for traffic loads.

The subgrade for curbs may be prepared separately, but it is preferable to prepare the subgrade for streets and curbs simultaneously in order to take advantage of the efficiency and effectiveness of larger equipment and to establish uniform support. After any underground utilities and sub-surface drainage features are installed and properly backfilled, subgrades should be carefully compacted to specified densities with controlled moisture. 95% of standard Proctor density is usually specified. In some cases, separate curbs are designed to extend to the bottom of the pavement structure, but where there are granular drainage courses or subbases, they should carry through under the curbs. Where there are compacted aggregate bases at lower elevations than curb bottoms, the bases should extend under the curbs and far enough beyond to support the curb construction equipment. Besides the curbs themselves, curb forms and curb slipform machines need firm support to produce straight, stable curbs at the specified elevations.

Curb forms should be straight, clean, and adequately interlocked and braced to hold to designed lines and grades. This is especially critical for combined curbs and gutters in order to assure the gutters will drain efficiently. It is also critical for tall straight curbs whose forms must be stable to maintain lines and elevations. Steel forms are preferred to wood forms because of their greater stability, but wood forms can be used for small projects and for curved sections if enough stakes and braces are employed. Forms should be sprayed with a release agent prior to placing the concrete, but the release agent should not be allowed on the reinforcing steel, if used. While the backs of formed curbs are usually vertical, exposed portions of front faces are often sloped or battered. Sloping formed faces require spacers or templates to maintain correct cross sections and are therefore more difficult to form. Slipformed curbs, on the other hand, are preferably constructed with battered or sloping back and front faces for greater stability, faster placement and more efficiency. It is not uncommon to have gaps or short sections in slipformed curbs filled in with formed sections. In these instances, it is important that the formed sections match the slipformed sections in cross-sections and textures.
Reinforcing steel in concrete curbs is not usually necessary or recommended if correct jointing is used. However, if formed curbs are to be reinforced with steel bars, the bars should be positioned and secured within the forms so that they will not be displaced during placement and consolidation of the concrete. The deformed bars should not extend through expansion joint material placed at tangents of radii, but should extend through any spacer plates used to hold the forms in position. In reinforced slipformed curbs, the reinforcing bars are laid out in front of the slipform machines and fed through positioning plates in the fronts of the machines as they advance. Reinforcing bars must be lap spliced appropriate lengths to develop continuity and the laps should be tied to keep them in place, unless ties would interfere in slipform operations.

Concrete can be placed directly from ready mixed concrete trucks into forms or into hoppers of slipform curb machines. The ready mixed concrete trucks usually operate on the subgrades of the streets being constructed, but if compacted aggregate base is already in place, precautions should be taken to avoid having the delivery trucks disturbing the compacted surface or tracking soil on to the base. If delivering ready mixed concrete trucks are to operate behind the curbs, it is essential that any underground utilities or sub-surface drainage trenches behind the curbs have been properly backfilled. As the low slump concrete required for curb and gutter construction is susceptible to stiffening rapidly, it is important to schedule the concrete delivery so that there is no delay in discharging the concrete from the ready mixed concrete trucks when they arrive at the site.

Concrete placed in forms can be struck off manually or by form riding machines. Concrete must be consolidated to avoid honeycomb and voids and it must be shaped to the proper cross sections. When finished manually, curb and gutter sections are shaped by drawing straightedges across templates or by mules shaped to be pulled along the tops of the forms. Curbs and gutters can be checked for drainage by covering them with burlap and carefully pouring water into the gutters to be sure there are no flat spots. Curbs and gutters should be textured with light broom finishes or by dragging wet burlap or artificial turf along the surfaces.

11. Testing for Quality

Concrete used in curbs should be tested for quality according to the requirements in ASTM C-94 at least once per day or once every 150 cubic yards of concrete delivered to a job site. Since curbs and curb and gutter sections may require less than one cubic foot per foot of length, 150 cubic yards can represent a very long length of curb, and more frequent testing may be desired, especially in hot weather. Tests may include checking for entrained air (ASTM C 231 or C 173), slump (ASTM C 143), temperature (ASTM C 1064), unit weight (ASTM C 138), and compressive strength (ASTM C 39). Concrete should be sampled according to ASTM C 172. The flexural strength tests should not be used for quality control. Slump tests are irrelevant for concrete that is successfully passing through a slipform curb machine. Assuming an approved mixture design produces concrete of a satisfactory quality, the main purpose for performing quality control tests during construction is to
confirm uniformity of production. If the consistency of the delivered concrete is satisfactory for efficient placement, the most useful quality control test is the unit weight test. This test is relatively easy and quick to perform and it will quickly detect changes in entrained air content and other variations in quality. Changes in unit weight should be investigated by testing for entrained air. ACI Certified Testing Technicians should perform the field sampling and testing.

12. Curing

As soon as concrete has been placed and finished, it must be cured to develop strength and durability. This important construction operation is essential in achieving the required properties of concrete and it must be carried out on the job site as specified or in accordance with acceptable standard industry practices. Curbs must be protected against loss of moisture, from rain damage, from traffic, and from extreme hot or cold temperatures. ACI 308, Standard Practice for Curing Concrete, is a valuable source of information on taking care of concrete after it has been placed. In normal construction weather, protection can be accomplished by completely covering all exposed surfaces with spray-on membrane curing compound. In extremely dry conditions with high temperature, low humidity and wind, recommendations in ACI 305R, Hot Weather Concreting, should be carefully followed to avoid plastic shrinkage cracking and other ill effects. In cool weather with high humidity, it may not be necessary to use curing compound, but changes in weather should be watched to be sure the concrete is protected adequately. In cold weather, concrete must be kept warm enough to develop its strength and durability, and recommendations in ACI 306R, Cold Weather Concreting, should be carefully followed.

13. Cutting Joints

Joint locations should be spaced with consideration for places that will affect curb movement as previously discussed, such as sharp curves and interruptions for inlets. Sawing is the preferred way to cut joints because it is difficult to tool joints to adequate depths in thick sections. However, joints have been impressed into curbs with tee-bars shaped to conform to the curbs' cross-sections. Sawing should be done as soon as possible without spalling the edges of the saw cuts. Forms must be removed in order to saw joints properly. Removal of the forms means that the front and rear surfaces of the curbs must be protected against drying as well as the saw cuts.

14. Backfilling

Curbs should be carefully backfilled as soon as they have enough strength to resist displacement and damage from the operations of grading and compacting. Backfilling protects the front and backsides of curbs, provides damp earth to supplement curing or other protective measures,
and protects curbs and new pavements from undercutting by runoff. If rainfall is expected soon after curbs are constructed, it is advisable to protect the backs of curbs with temporary berming or diversion channels to avoid undercutting that is difficult to repair or may even lead to failure of new curb sections.

15. Summary

Concrete curbs can be quickly and efficiently constructed with modern slipform equipment supplied with carefully controlled, high quality concrete delivered by ready mixed concrete trucks. The use of standardized cross sections for all commonly used types of curbs or curb and gutters may reduce costs. Concrete curbs confine pavement structures, resist the abuses of snowplows, and improve visibility of the pavement edges.

Concrete curbs in some areas are exposed to the most severe environments of snow, ice, deicing chemicals, and snow removal equipment. High quality concrete, good construction procedures, and thorough curing are essential to construct curbs to serve well under these conditions.

Concrete curbs outlining the edges of streets and parking lots offer many functional as well as esthetic advantages. They mark the edges of pavements, help confine vehicles to the pavements, improve drainage, and make sweeping and cleaning easier.

Today’s concrete technology can produce these curbs to provide many benefits to the public for many years into the future.
16. References


5. “Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete,” ACI 2111.1, American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333

6. “Hot Weather Concreting,” ACI 305R, American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333

7. “Cold Weather Concreting,” ACI 306R, American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333

8. “Standard Practice for Curing Concrete,” ACI 308, American Concrete Institute, P.O. Box 9094, Farmington Hills, MI 48333


10. American Society for Testing and Materials (ASTM), vol. 04.02 “Concrete and Aggregates,” ASTM, West Conshohocken, PA