



Concrete Craftsman Series

Placing and Finishing Decorative Concrete Flatwork



CCS-5(16)



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CCS-5 Placing and Finishing Decorative Concrete Flatwork
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INTRODUCTION

Concrete contractors place and finish concrete for a variety of applications. Proper placing and finishing of decorative concrete requires specialized skills using decorative concrete products and techniques not required for most concrete placements. These skills are in addition to the proper placing, finishing, and curing skills needed for routine concrete placements that are covered by existing flatwork finisher resources and programs.

The decorative concrete industry is growing fast. As a result, there is a need for education and information from credible sources. The standards of quality for this growing industry must be maintained and increased. This document was produced with the intent of raising the quality of education for the decorative concrete industry. Quality of construction will progress by continually improving the level of craftsmanship.

Many of the skills associated with decorative concrete flatwork are not presently covered in existing concrete flatwork resources. This document supplements existing resources by providing knowledge of the materials, equipment, and techniques required to successfully install decorative concrete flatwork. Knowledge of traditional concrete flatwork techniques is recommended for full understanding of this document. Decorative concrete topics covered herein include:

- Mixture design for decorative concrete mixtures;
- The use of integral color and dry shake color hardeners;
- The identification and uses of decorative finishing tools and equipment (such as stamping mats and stencils);
- The use of surface retarders and set-retarding admixtures to produce exposed aggregate surfaces;
- Stamping and texturing concrete;
- Seeding fresh concrete surfaces with decorative aggregate;
- Decorative treatments for stair treads and risers; and
- Cleaning and sealing methods for decorative concrete.

This document also covers topics that are universal to concrete flatwork construction:

- Jobsite and personal safety;
- Ensuring the design adheres to Americans with Disabilities Act (ADA) guidelines;
- Preplacement site preparation; and

- Identification and uses of concrete finishing tools.

Additionally, two chapters of texture samples and project examples are included. Architectural cast-in-place walls, chemical stains, decorative overlays, decorative scoring, and other topical finishes are not included in this document.

CHAPTER 1: SAFETY

A well-conceived and well-executed safety program is necessary to keep everyone at the jobsite aware of and protected against possible hazards. Failure to follow safety regulations and to use personal protective equipment (PPE) can lead to injuries. In addition to concern for the injured person, accidents can disrupt the flow and quality of work, further impacting the project. Every contracting company should have a written safety policy that sets out clear lines of authority for training and retraining personnel in safety regulations and procedures related to their construction specialty.

While many safety rules are the same for all types of concrete work, decorative concrete work presents special situations. In addition to the minimum requirements of the Occupational Safety and Health Administration (OSHA) Standards for the Construction Industry 29 CFR 1926,¹ these basic rules should always be followed:

- Minimum safety equipment (Fig. 1.1) for all concrete work includes hard hats, safety glasses, safety vests, full-length pants, long-sleeved shirts, sturdy leather footwear (boots or shoes, no sandals), and ear protection. Additional PPE is necessary for specific tasks and activities.
- When working with wet concrete, impervious gloves, impervious boots, and safety glasses should be worn. Fresh concrete can cause chemical burns and eye injuries.
- Hard hats should be worn when any overhead danger is present.
- Safety glasses and face shields should be worn when operating concrete cutting or chipping tools and equipment such as grinders, saws, and chipping hammers.
- Approved respirators should be worn when handling dust-, mist-, or fume-producing products or performing dust-, mist-, or fume-producing operations such as cutting, grinding, or buffing concrete or applying coatings, sprays, colorants, or similar products that may be toxic.
- Hearing protection should be worn when operations or equipment create noise levels that prevent normal conversation at a distance of 3 ft (1 m).
- Portable electric tools should be in good condition and equipped with the appropriate guards. In addition, portable electric tools should be of the double insulated type or protected by a ground fault circuit interrupter. Ground prongs should not be removed.



Fig. 1.1—Hard hat, eye protection, safety vest, long-sleeved shirt, long pants, boots, and ear protection are minimum safety equipment for decorative concrete work. Dust masks should be worn when necessary.

- Extension cords should be at least 14-gauge, approved for hard or extra hard service, and in good condition.
- Extension cords should be kept out of walkways and protected from sharp objects and vehicular traffic.
- When handling wet concrete, an adequate supply of potable water should be available for hand washing and flushing of the eyes.
- Any exposed reinforcing bar that could create an impalement hazard should be protected by approved caps.
- Material Safety Data Sheets for all hazardous materials should be onsite and available for reference.
- Containers of hazardous materials should be labeled in accordance with the OSHA Hazard Communication Standard.²
- Solvent-based sealers are flammable and should be kept away from all sources of ignition. When used indoors, the area must be well ventilated.
- Reduce the risk of trip and fall accidents around formwork and exposed reinforcement by barricading the work area. Keep the jobsite clean — even if it's not your job.
- Bend with your knees and lift with your legs, not your back. Lift only what you can comfortably handle.
- Keep your fingers away from the metal joints of a concrete truck chute. Should a finger be caught in the gap of the joint as the chute is dropped from its stored position, it can slice through a finger like scissors through cloth.

Helpful training information is available online through the OSHA Training Institute³ and the OSHA 2254 document.⁴

REFERENCES

1. Occupational Safety and Health Administration, "Part 1926 – Safety and Health Regulations for Construction," United States Department of Labor, Washington, DC.

2. Occupational Safety and Health Administration, "Part 1910.1200 – Hazard Communication Standard," United States Department of Labor, Washington, DC.

3. Occupational Safety and Health Administration, "OSHA Training Institute," United States Department of Labor, Washington, DC. <http://www.osha.gov/dte/oti/index.html>. (last accessed 11/22/2015)

4. Occupational Safety and Health Administration, "Training Requirements in OSHA Standards and Training Guidelines," OSHA 2254, United States Department of Labor, Washington, DC, 1998, <http://www.osha.gov/Publications/osh2254.pdf>. (last accessed 11/22/2015)

CHAPTER 2: LAYOUT CONSIDERATIONS

A contractor's work must comply with Americans with Disabilities Act (ADA) Guidelines.¹ Failure to comply with ADA Guidelines could result in work being rejected or subjected to a lawsuit. Always review plans and as-built conditions to determine if the work to be installed will comply with ADA. Contractors must know the basics of ADA Guidelines as a minimum to avoid problems. An up-to-date ADA reference guide should be purchased and studied to avoid such problems. The following is only a brief overview of ADA Guidelines and should not be considered a complete guide.

ADA Guidelines

Purpose of ADA — ADA Guidelines are required by the U.S. Federal Government and set requirements for accessibility by individuals with disabilities to places of public accommodations and commercial facilities. These guidelines are to be applied during the design, construction, and alteration of such buildings and facilities to the extent required by regulations issued by Federal agencies, including the Department of Justice, under the Americans with Disabilities Act of 1990.

Terms used in ADA

ADA Guidelines use the following terms pertaining to exterior concrete work:

Cross Slope — The slope that is perpendicular to the direction of travel.

Curb Ramp — A short ramp cutting through a curb or built up to it.

Detectable Warning — A standardized surface feature built in or applied to walking surfaces or other elements to warn of hazards on a circulation path.

Ramp — A walking surface that has a running slope steeper than 1:20.

Running Slope — The slope that is parallel to the direction of travel.

Tactile — An object that can be perceived using the sense of touch.

Vehicular Way — A route intended for vehicular traffic, such as in a street, driveway, or parking facility.

Walk — An exterior prepared surface for pedestrian use, including pedestrian areas such as plazas and courts.

Requirements for Flatwork

Accessible Route

At least one accessible route within the boundary of the site is required from public transportation stops, accessible parking, accessible passenger loading zones, and public streets or sidewalks to the accessible building entrance that they serve. An accessible route is a continuous, unobstructed path connecting all accessible elements and spaces of a building or facility. Interior accessible routes may include corridors, floors, ramps, elevators, lifts, and clear floor space at fixtures. Exterior accessible routes may include parking access aisles, curb ramps, crosswalks at vehicular ways, walks, ramps, and lifts. To the maximum extent feasible, the accessible route is required to coincide with the route for the general public.

ADA requirements for accessible routes include:

- A minimum clear width for an accessible route of 36 in. (915 mm), with some exceptions;
- A surface for an accessible route that is stable, firm, and slip-resistant. Changes in elevation up to $\frac{1}{4}$ in. (6 mm)

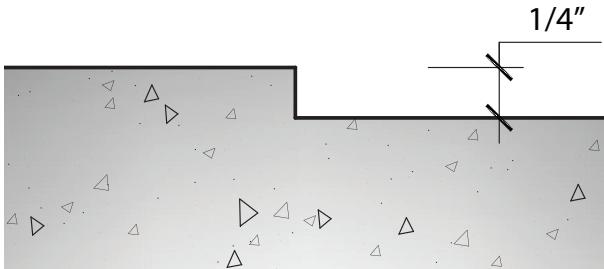


Fig. 2.1—A maximum vertical elevation change of $\frac{1}{4}$ in. (6 mm) is allowed between accessible route surfaces. (Note: 1 in. = 25.4 mm)

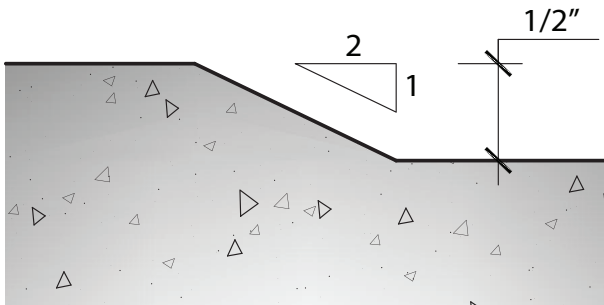


Fig. 2.2—A maximum vertical elevation change of $\frac{1}{2}$ in. (13 mm) is allowed between accessible route surfaces if beveled at a 1:2 slope. (Note: 1 in. = 25.4 mm)

may be vertical and without edge treatment (Fig. 2.1). Changes in elevation between $\frac{1}{4}$ and $\frac{1}{2}$ in. (6 and 13 mm) are to be beveled with a slope no greater than 1:2 (Fig. 2.2). Changes in elevation greater than $\frac{1}{2}$ in. (13 mm) are required to meet the requirements for ramps; and

- An accessible route with a running slope greater than 1:20 is required to comply with the requirements for ramps.

Curb Ramps

Curb ramps are required to be provided wherever an accessible route crosses a curb. ADA requirements for curb ramps include:

- Slopes of curb ramps are required to be at the least possible slope. The maximum slope of a ramp in new construction is 1:12.

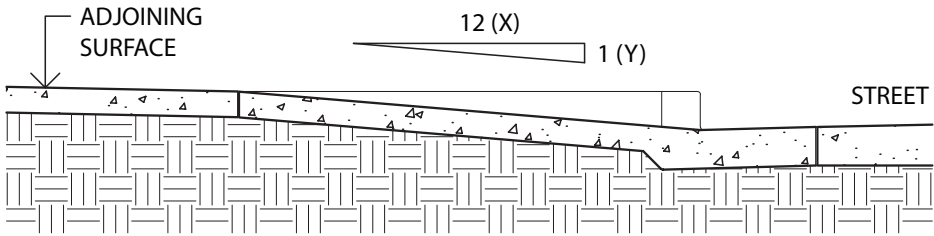


Fig. 2.3—Slope of curb ramp. Slope = $Y:X$, where X is a level plane.

- The slope is required to be measured per Fig. 2.3. Transitions from ramps to walks, gutters, or streets are required to be flush and free of abrupt changes. Maximum slopes of adjoining gutters, road surface immediately adjacent to the curb ramp, or accessible route are not allowed to exceed 1:20;
- The minimum width for curb ramps is 36 in. (915 mm), exclusive of flared sides (Fig. 2.4). The maximum slope of the flare is limited to 1:10 (Fig. 2.4) where it is not protected by handrails or guardrails;
- Curb ramps with returned curbs may be used where pedestrians would not normally walk across the ramp (Fig. 2.5);
- Built-up curb ramps are required to be located so they do not project into vehicular traffic lanes (Fig. 2.6).

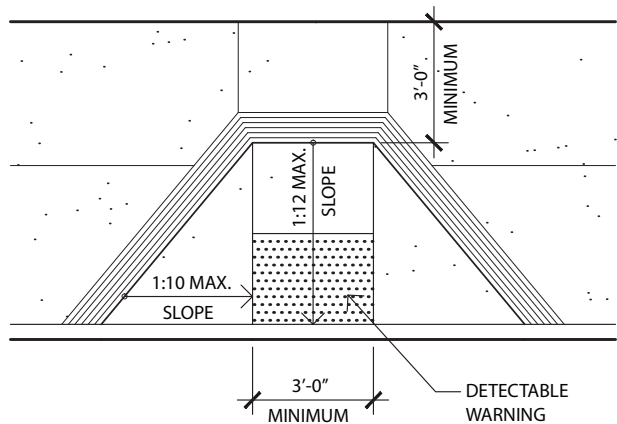


Fig. 2.4—Curb cut ramp (Note: 1 ft = 0.305 m)

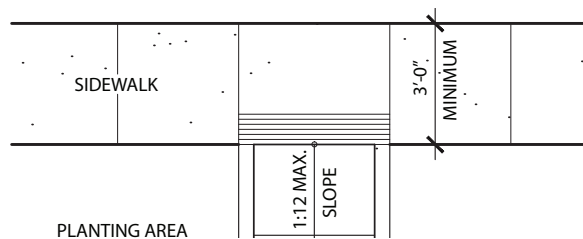


Fig. 2.5—Curb ramp with returned curbs (Note: 1 ft = 0.305 m)

Ramps

Any part of an accessible route with a slope greater than 1:20 must meet the ADA requirements for a ramp. These include:

- The least possible slope is required to be used for any ramp. The maximum slope of a ramp in new construc-

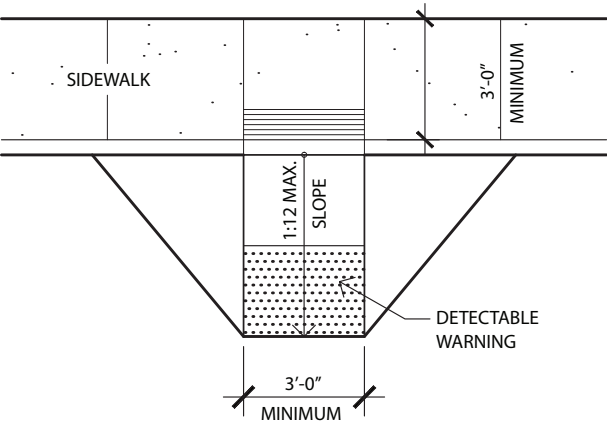


Fig. 2.6—Built-up curb ramp. Note: Not allowed to project into vehicular path (Note: 1 ft = 0.305 m)

tion is 1:12, which is 8.33% or 1 in./ft (83 mm/m). The maximum rise, regardless of length, for any run is 30 in. (760 mm) (Fig. 2.7);

- A minimum clear width of 36 in. (915 mm) (Fig. 2.7);
- Landings are required at the bottom and top of each ramp and each ramp run. Landings are required to have the following features (Fig. 2.7):
 - The landing is required to be at least as wide as the widest ramp run leading to it;
 - The landing length is limited to a minimum of 60 in. (1525 mm) clear; and
 - If ramps change direction at landings, the minimum landing size is 60 × 60 in. (1525 × 1525 mm);
- A cross slope for ramp surfaces no greater than 1:50 is required;
- Ramps and landings with drop-offs are required to have curbs, walls, railings, or projecting surfaces that prevent people from slipping off the ramp; and
- Outdoor ramps and their approaches are required to be designed so that water will not accumulate on walking surfaces.

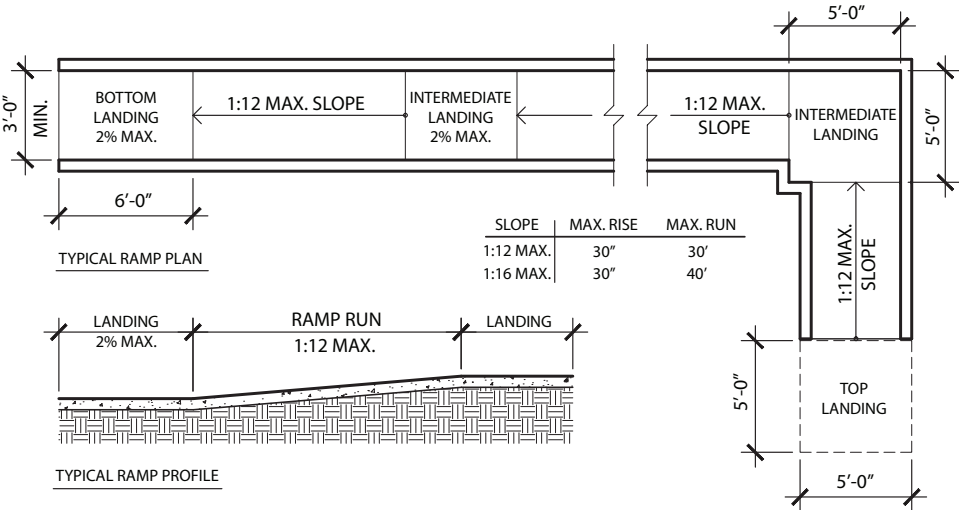


Fig. 2.7— Typical ramp plan and profile (Note: 1 in. = 25.4 mm; 1 ft = 0.305 m)

Stairs

ADA requirements for stairs include:

- On any given flight of stairs, all steps are required to have uniform riser heights and uniform tread widths. Stair treads can be no less than 11 in. (280 mm) wide, measured from riser to riser. Risers are not allowed to exceed 7 in. (177 mm) in height (Fig. 2.8). Open risers are not permitted;
- The undersides of nosings are not allowed to be abrupt. The radius of curvature at the leading edge of the tread can be no greater than $\frac{1}{2}$ in. (13 mm) (Fig. 2.9). Risers are required to be sloped or the underside of the nosing is required to have an angle not less than 60 degrees from the horizontal. Nosings can project no more than 1.5 in. (38 mm) (Fig. 2.8).
- Outdoor stairs and their approaches are required to be designed so that water will not accumulate on walking surfaces.

Detectable Warnings on Walking Surfaces

Detectable warnings (Fig. 2.10) are required to consist of raised, truncated domes with a base diameter of 0.9 to 1.4 in. (23 to 36 mm), a nominal height of 0.2 in. (5 mm), and a nominal center-to-center spacing of 1.6 to 2.4 in. (41 to 61 mm) and are required to contrast visually with adjoining surfaces, either light-on-dark or dark-on-light.

Although detectable warnings are not required in the 2010 ADA guidelines, except on transit platforms, the local building code may contain additional requirements.

Summary

An accessible route is typical at virtually all new construction, including retail centers, office buildings, plazas, parks, public sidewalks, transportation facilities, and residential buildings.

The maximum cross slope on an accessible route is 2% or 1:50 or slightly less than $\frac{1}{4}$ in./ft (20 mm/m). For

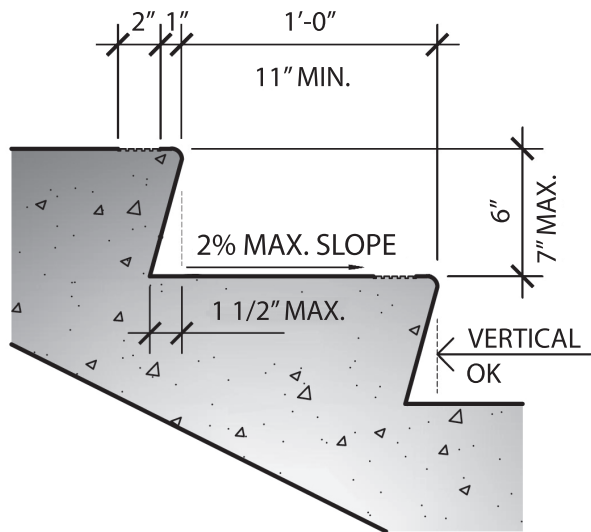


Fig. 2.8—Requirements for stairs include 11 in. (280 mm) minimum treads, 7 in. (177 mm) maximum risers, a nonslip surface, a grooved strip with contrasting color, and $\frac{1}{2}$ in. (13 mm) maximum radius nosing (Note: 1 in. = 25.4 mm)

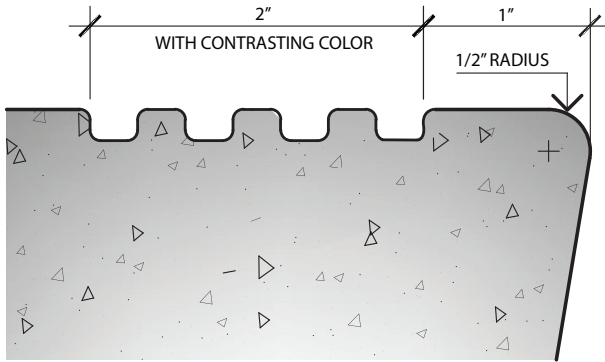


Fig. 2.9—Tooled warning strip (Note: 1 in. = 25.4 mm)

example, you cannot have more than 1 in. (25 mm) cross fall (side to side) on a 50 in. (1.25 m) wide walk.

The maximum running slope (fall in the direction of travel) is 8.33% or 1:12. Therefore, you cannot have more than 1 in. (25 mm) fall in any given 12 in. (300 mm) length of walk.

Any part of an accessible route with a slope greater than 5% or 1:20 is considered a ramp.

Keep in mind that the term “maximum” is exactly that. It is preferred to stay conservatively under the maximum percentages so as not to go even slightly beyond the maximum, otherwise your work may be subject to corrective repairs, removal, or a lawsuit.

Contractors should also consider tolerances when constructing ramps. It is best to construct the ramp below the maximum allowable slope to accommodate tolerances within the specifications. Therefore, a ramp with a maximum slope of 8.33% might best be constructed at 8.00%, or less, to allow for tolerances during placement and finishing of concrete. Contractors should address this issue early through the request for information (RFI)

process to gain clarification and steer clear of any violations of ADA Guidelines.

REFERENCES

1. *2010 ADA Standards for Accessible Design*, Department of Justice, Washington, DC, Sept. 15, 2010, 275 pp.



Fig. 2.10—Precast concrete truncated dome tiles at a handicapped access ramp

CHAPTER 3: SOILS, SUBGRADE, AND BASE REQUIREMENTS

Soils Report

If available, review the soils report (also known as a geotechnical investigation report) for the recommendations contained therein. The report has three purposes: (1) evaluate geotechnical conditions at the site; (2) identify significant geotechnical or geologic issues that would impact site development; and (3) provide geotechnical recommendations for design and construction of the proposed development, or more specifically, the concrete work.

Typically, concrete is referred to as a rigid pavement in the report. The soils report will often provide sections and designs for pedestrian and vehicular areas, driveways, fire lanes, structures, walls, footings, curb and gutter, and other concrete flatwork.

The soils report should be reviewed for items that may affect the concrete sitework, including subgrade preparation and cement type and corrosion protection:

Subgrade Preparation

Areas planned for concrete pavement or flatwork (sidewalks) are often overexcavated to a defined depth (for example, 12 or 24 in. [300 or 600 mm]) below the existing or proposed subgrade, whichever is deeper. The excavated soil is reviewed and possibly tested by the geotechnical firm to determine if it is suitable for use as compacted structural fill. If it is determined to be suitable, then the fill soil or import soil, if necessary, is placed in thin, loose lifts, moisture-conditioned as necessary to near optimum moisture content, and recompact to 90 or 95% relative compaction per the soils report.

If another contractor trenches through the prepared, compacted subgrade (for an electrical conduit, plumbing, or irrigation work, for example), verify that their backfill has been compacted, tested, and accepted by the geotechnical firm's on-site inspector. You do not want the subgrade to fail under your paving at a later date.

A concrete contractor is wise to exclude subgrade preparation from their proposal. Recompaction of existing on-site soil can be difficult to achieve under some circumstances and is best left to a grading contractor.

Cement Type and Corrosion Protection

The geotechnical firm will evaluate the soils through laboratory testing to determine what steps need to be taken to ensure slabs-on-ground are not subject to chemical attack from the underlying soils. The engineer will determine cement type (I/II or V) and the water-cementitious materials ratio (w/cm) required to protect the concrete.

Other Information

Slabs-on-ground should be placed on properly compacted subgrade as described within the soils report. In addition, the report may recommend the following:

- Concrete thickness;
- Aggregate base thickness;
- Reinforcing steel;
- Compressive strength;
- Water-cementitious materials ratio;
- Supplementary cementitious materials required to protect the concrete from the sulfate-rich or low-pH soils; and
- Recommended joint (contraction joint) spacing, depth of contraction joints (typically one-fourth the depth of the slab) for each type of paving.

For example, pedestrian paving, alleyways, and concrete pavements (heavy truck) may each have their own design. Often, a table is contained within the soils report showing the structural sections required for various loadings.

It is highly recommended that the concrete contractor compare the recommendations in the soils report to the drawings and specifications. It is best to adhere to the most stringent design required. All conflicts in the documents, however, should be disclosed to the Owner, General Contractor, or Contracting Agency.

CHAPTER 4: FORMING, REINFORCEMENT, DOWELS, AND JOINTING

Forming is a critical task for decorative concrete paving. Forming creates the desired layout, sets the elevations for the paving, and determines the placement sequence.

Forming for decorative concrete paving typically consists of using standard sized lumber: 2x4 (38 x 89 mm) lumber for 4 in. (100 mm) thick concrete, 2x6 (38 x 140 mm) lumber for 6 in. (150 mm) thick concrete, and 2x8 (38 x 184 mm) lumber for 8 in. (200 mm) thick concrete. The lumber is held in place by stakes. The stakes are typically made of wood or metal. The choice of material depends on the firmness of the subgrade and the forming system that a contractor chooses.

Typically, the location of the forming is dictated by the layout shown on the plans. The contractor should follow the dimensions on the plan where shown and not scale the drawings. If a dimension cannot be determined from the plans, the contractor should request a clarification from the General Contractor or design professional (Architect, Landscape Architect, or Engineer). In addition to the perimeter forming, there is often interior forming to provide planters, blockouts, banding, or expansion joints.



Placing in lanes provides accessibility and space for multiple operations.

Before forming can begin, the decorative concrete contractor should consider:

- Are adequate dimensions shown on the drawings for layout and forming purposes?
- Are elevations shown on the drawings? If so, do they provide adequate slope to drains and is the paving sloping away from structures? The recommended minimum slope for textured concrete paving is 1% slope. Any slope less than this can create ponding water or “birdbaths”.
- Do the slopes on the plans conform to ADA requirements?
- The sequence of placing concrete will determine the forming. Typically, the perimeter forming is placed, followed by the interior forms. The interior forms may be for banding, construction joints, full-depth expansion joints, or where dowels are required. Furthermore, the interior forms may be required due to a change in color or texture, to allow production, or for accessibility purposes.

A contractor needs to proactively determine problems or conflicts within the plans and specifications before forming and certainly before concrete is placed. For example, if the given elevations on a plan cause the crossfall of a sidewalk to exceed 2%, then the contractor must let others know that this is a violation of ADA and the elevations need to be revised. Once the concrete has been placed, it is often too late to raise an issue with the plans or specifications.

There are often dimension or elevation “busts”—that is, inconsistencies that do not work with the on-site conditions, particularly when new construction is tying into existing construction. Again, the contractor needs to identify the problems, preferably before beginning work. Problems with the plans and specifications are typically resolved through the request for information (RFI) process, wherein a contractor states the conflict on a written form and the responsible party answers the RFI before work is begun.

Allowance for Accessibility and Production

In the past, concrete paving was constructed in a checkerboard pattern, instead of in lanes (Fig. 4.1), in an effort to permit the earlier placements to shrink and control cracking. Experience has shown that this is no longer recommended, especially for decorative concrete, because:

- Access is more difficult;
- The joints between the adjacent placements are not as smooth (a saw-cut or tooled contraction joint is preferable to an expansion joint);
- Color and texture uniformity are lessened by the excessive number of placements required; and
- Costs are increased when using a checkerboard pattern.

A concrete lane formed between 10 and 20 ft (3 and 6 m) in width is best for decorative concrete. The actual width would depend on the following factors:

- **Type of Finish:** Seeded aggregate will require a closer spacing, whereas a broom finish can be at a wider spacing.
- **Contraction Joints:** The plans may call for saw-cut contraction joints at 10 ft (3 m) on center each way. This would require that the concrete placement lane be 10 or 20 ft (3 or 6 m) wide—that is, a multiple of 10 ft (3 m).
- **Decorative Joints:** The plans may call for the paving to receive a saw-cut or tooled pattern with a given spacing. For example, a 3 x 3 ft (0.9 x 0.9 m) joint pattern would require the paving lane to be divisible by 3, resulting in a lane width of 12, 15, or 18 ft (3.6, 4.5, or 5.4 m).



Fig. 4.1—Forming over a waterproofing membrane. Concrete to be placed in lanes as opposed to a checkerboard



Fig. 4.2—Light gray concrete banding with dark gray concrete fields at a motor court

Reinforcement

Decorative concrete paving (Fig. 4.3) is typically reinforced with steel. The type, size, and spacing of the reinforcing steel is usually called out on the drawings, specifications, and soils report. Reinforcement for decorative concrete paving consists of welded wire reinforcement, steel reinforcing bars, fibers, or a combination of these.

Welded Wire Reinforcement

Welded wire reinforcement (Fig. 4.3) consists of pieces of wire welded together to form a grid pattern. The size of the grid pattern used in decorative concrete paving is typically 4 x 4 in. up to 8 x 8 in. (102 x 102 mm up to 203 x 203 mm). Because the wires are welded in a mat, the wire spacing does not change when concrete is placed. Common wire sizes are W1.4 (MW9), W2.9 (MW19), and W4.0 (MW26), while common spacing is either 4 or 6 in. (102 or 152 mm). However, welded wire reinforcement is available in many combinations of wire size and spacing.

Most often, 6x6-W1.4xW1.4 or 6x6-W2.9xW2.9 (152 x 152-MW9 x MW9 or 152 x 152-MW19 x MW19) is specified for decorative concrete paving. The first two numbers,

6x6 (152 x 152), denote the spacing of the cross wires and long wires, which in this callout is 6 in. (152 mm) on center each way. The second set of numbers call out the wire size, W1.4 or W2.9 (MW9 or MW19). Depending on the spacing and size of wire, wire reinforcement is available in rolls or mats.

Welded wire reinforcement, especially in rolls, presents a challenge to control the location of the mesh during concrete placement. In addition, care must be taken to support the welded wire reinforcement, as necessary, to keep it from being pushed down into the ground. Heavier gauge wire, in mats (not rolls), can more easily be supported during the placement of concrete.

A contractor may be held liable if welded wire reinforcement, or reinforcing steel bar, is not properly positioned in the concrete paving.

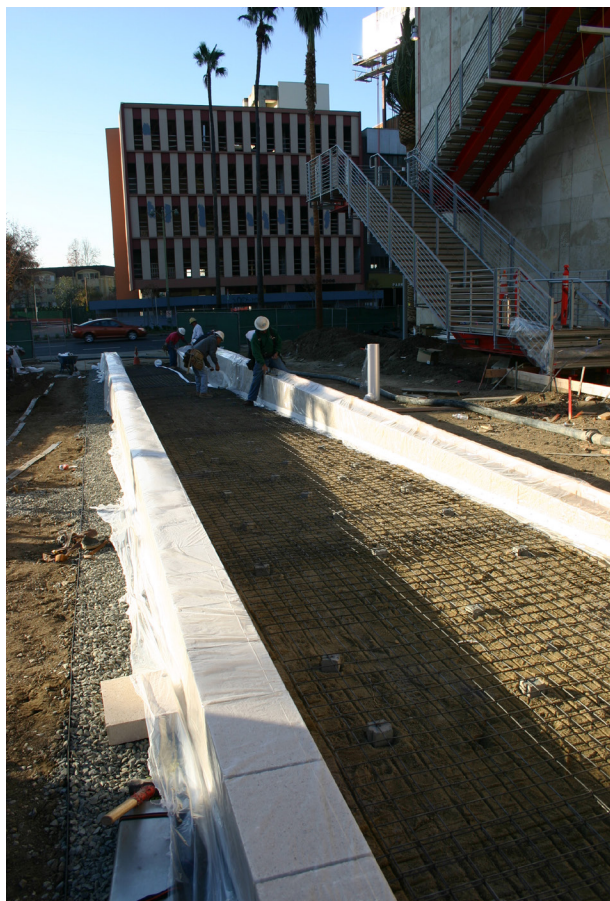


Fig. 4.3—Welded wire reinforcement placed on concrete chairs. Mesh is W4 (MW26) wire on 4 in. (100 mm) centers

Reinforcing Steel Bar

Reinforcing steel bars are usually stocked in 20 ft (6 m) lengths. The bars are typically deformed. That is, a pattern is rolled onto the surface of the bars that allows the concrete to grip the bar. There are several grades of reinforcing steel available, but Grade 60 (420) is by far the most common. Grade 60 has a minimum yield strength of 60,000 psi (420 MPa). The size designations up through No. 8 (No. 25) are the number of eighths of an inch (millimeters) in the nominal diameter of a plain round bar having the same weight per unit length as the deformed bar. For example, the three most common bar sizes for decorative concrete paving are the No. 3, No. 4, and No. 5 (No. 10, No. 13, and No. 16). The No. 3 bar has a 3/8 in. nominal diameter, the No. 4 bar has a 4/8 in. or 1/2 in. nominal diameter, and the No. 5 bar has a 5/8 in. nominal diameter (the No. 10 bar has a 10 mm nominal diameter, the No. 13 bar has a 13 mm nominal diameter, and the No. 16 bar has a 16 mm nominal diameter).

The size and spacing of the reinforcing steel bars are typically called out on the drawings. However, the specifications and soils report may contain this information as well. Pedestrian paving is typically 4 in. (100 mm) thick concrete, and it can be found to be reinforced with 6x6-W1.4xW1.4 (152 x 152-MW9 x MW9) welded wire reinforcement, No. 3 (No. 10) bars at 24 in. (600 mm) on center each way, or No. 3 (No. 10) bars at 18 in. (450 mm) on center each way. Each project is unique, and a contractor should not assume steel reinforcement based on a previous project. Vehicular paving is typically 6 in. (150 mm) thick, and it is often reinforced by welded wire reinforcement with a larger gauge wire such as 6x6-W2.9xW2.9 (152 x 152-MW19 x MW19), or larger bars at closer spacings. For example, No. 4 (No. 13) bars at 18 in. (450 mm) on center each way or No. 4 (No. 13) bars at 12 in. (300 mm) on center each way.

Spacer Blocks

Welded wire reinforcement and steel reinforcement need to be held in position during concrete placement. Typically in a lightly loaded slab, the concrete reinforcement is contained in the top half of the concrete paving. A 4 in. (100 mm) thick slab should employ the use of 2 x 2 x 2 in. (50 x 50 x 50 mm) concrete spacer blocks or other chairing devices, whereas a 6 in. (150 mm) slab uses 3 x 3 x 3 in. (75 x 75 x 75 mm) concrete spacer blocks (Fig. 4.4). The blocks are spaced as needed to hold the reinforcement at the proper height and provide adequate support during placement of the concrete.

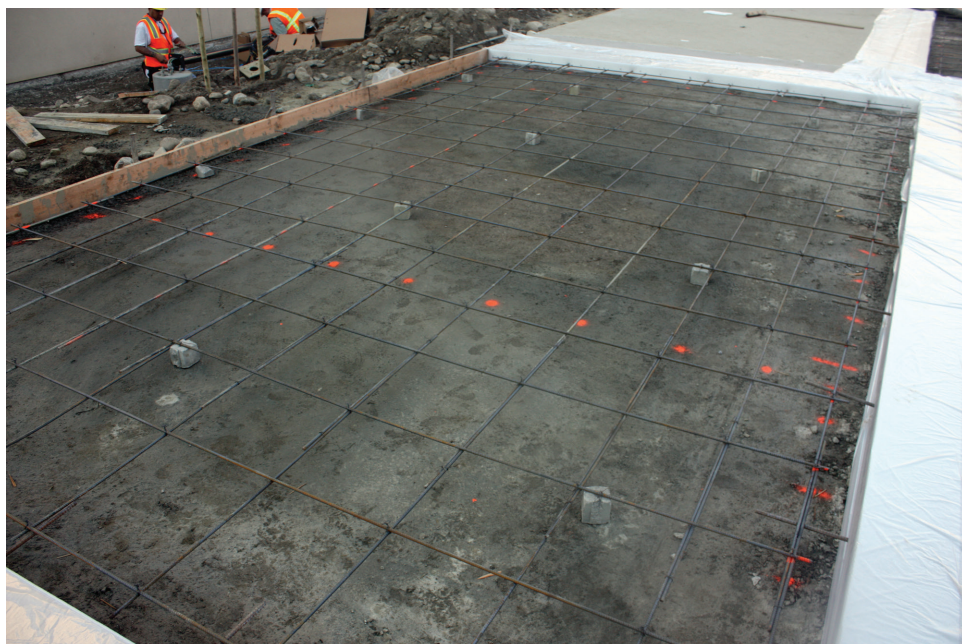


Fig. 4.4—Reinforcing steel bar placed on 3 in. (75 mm) thick precast concrete spacer blocks for 6 in. (150 mm) thick paving

Dowels

Dowels (Fig. 4.5) are used between adjacent concrete placements to allow the slab to move horizontally in the same longitudinal direction as the dowel without restraint. Dowels are a means to allow for load transfer across construction or control joints. Dowels are typically placed at 12, 18, or 24 in. (300, 450, or 600 mm) on center, depending on the loading requirements. In the past, smooth steel dowels were placed in the slab through holes drilled in the edge form. After the form was stripped, the end of the smooth dowel was either greased or placed in a cylindrical cardboard sleeve. In this way, the dowel was fixed on one end and allowed to move on the other end, hence the term “slip” dowel. This allowed horizontal movement but restricted the vertical movement of the slabs.

Today there are time-saving products available for dowels. One system uses plate dowels, either square or diamond shaped, encased in plastic sleeves. The plastic sleeve is attached to the edge form with nails prior to concrete being placed. Once the form is stripped, the plate dowel is inserted into the void created by the plastic sleeve. The use of these products in exterior applications should be evaluated for possible issues in environments subject to cycles

of freezing and thawing. Another system uses a round or square dowel, plastic base, and sleeve attached to the edge form prior to concrete placement. The form and base are removed after placing and the steel dowel is inserted into the sleeve that is encased in concrete. Both product types claim to reduce installation costs by 50%. They both eliminate drilling of the forms and allow the slab to move horizontally while restricting the movement vertically.

Dowels are essential between adjacent concrete placements to restrict vertical movement. Concrete paving that moves vertically can create a tripping hazard, cause water to pond, and may be cause for removal and replacement. It is very important that dowels are placed perpendicular to the joint and level so as to not cause restriction in horizontal slab movement.



Fig. 4.5—Expansion joint material, steel dowels, and plastic sheeting for protection; ready for a concrete placement

Microfibers and Macrofibers

Microfibers and macrofibers are secondary reinforcement. If used, microfibers are more common in decorative concrete because they are less visible in the concrete than macrofibers. Neither are meant to replace welded wire reinforcement or reinforcing bars. Microfibers may reduce cracking due to plastic shrinkage and thermal expansion and contraction, reduce permeability and absorption, and increase durability of concrete. Fibers are added directly to the concrete mixture either at the batch plant or at the jobsite. When added at a jobsite, the concrete needs to be mixed at a high speed during addition of the fibers and then at mixing speed for a minimum of 40 revolutions, after the addition of fibers. Consult with the fiber manufacturer to verify specific requirements. The dosage rate for fibers typically falls in a range of 0.5 to 2.0 lb/yd³ (0.3 to 1.2 kg/m³) depending on the application and the manufacturer. Fibers do not require additional water or admixtures when they are added to the concrete.

Decorative concrete typically uses finer, shorter fibers, ranging in length from $\frac{1}{4}$ to $\frac{3}{4}$ in. (6 to 19 mm) depending on the manufacturer, to minimize the appearance of the fiber

in the finished concrete product, whether that is paving, curbs, stairs, or walls. The fibers will typically be visible in the final product. Therefore, they may need to be burned off with a torch.

Jointing

Isolation Joints

Isolation joints (also known as expansion joints) and contraction joints (also known as control joints) are placed in decorative concrete paving to minimize random shrinkage cracking. Isolation joints should be minimized. They are typically placed against structures, walls, existing concrete, and other vertical restraints. They can be placed at re-entrant corners to reduce cracking with more certainty than a contraction joint. All re-entrant corners should have an isolation, construction, or contraction joint. Where this is not possible, a minimum of two No. 4 reinforcing bars 4 ft (1.2 m) in length should be placed on a 45-degree angle to the corner. Isolation joints should not be used to create a checkerboard placement—this is not necessary.

Contraction Joints

Contraction joints are placed in concrete to minimize shrinkage cracking. The joints are spaced ideally to form square panels. Concrete that is 4 in. (100 mm) thick should have contraction joint spacing no more than 10 ft (3 m) on center, while 6 in. (150 mm) thick concrete should have contraction joints no more than 15 ft (4.6 m) on center. The longer dimension of a concrete panel should not exceed the shorter dimension by more than 50%. For example, a 4 in. (100 mm) thick panel could be 7 x 10 ft (2.1 x 3 m). However, if a panel is 5 ft (1.5 m) wide, the joints should be less than 10 ft (3 m) apart or they will probably crack on their own. Always try to be as conservative as possible. A concrete mixture with a lower water-cementitious materials ratio will generally have less shrinkage cracking. In addition, a properly prepared, compacted, and leveled subgrade will aid in minimizing shrinkage cracking as it provides a low coefficient of friction as the slab contracts during curing.

Cracking will be uncontrolled unless contraction joints are placed in the slab similar to Fig. 4.6 and 4.7.

Residential driveway and front entry

A joint layout for a residential driveway and front entry is illustrated in Fig. 4.6. The concrete fields are placed in two separate placements. In this example, they are saw-cut

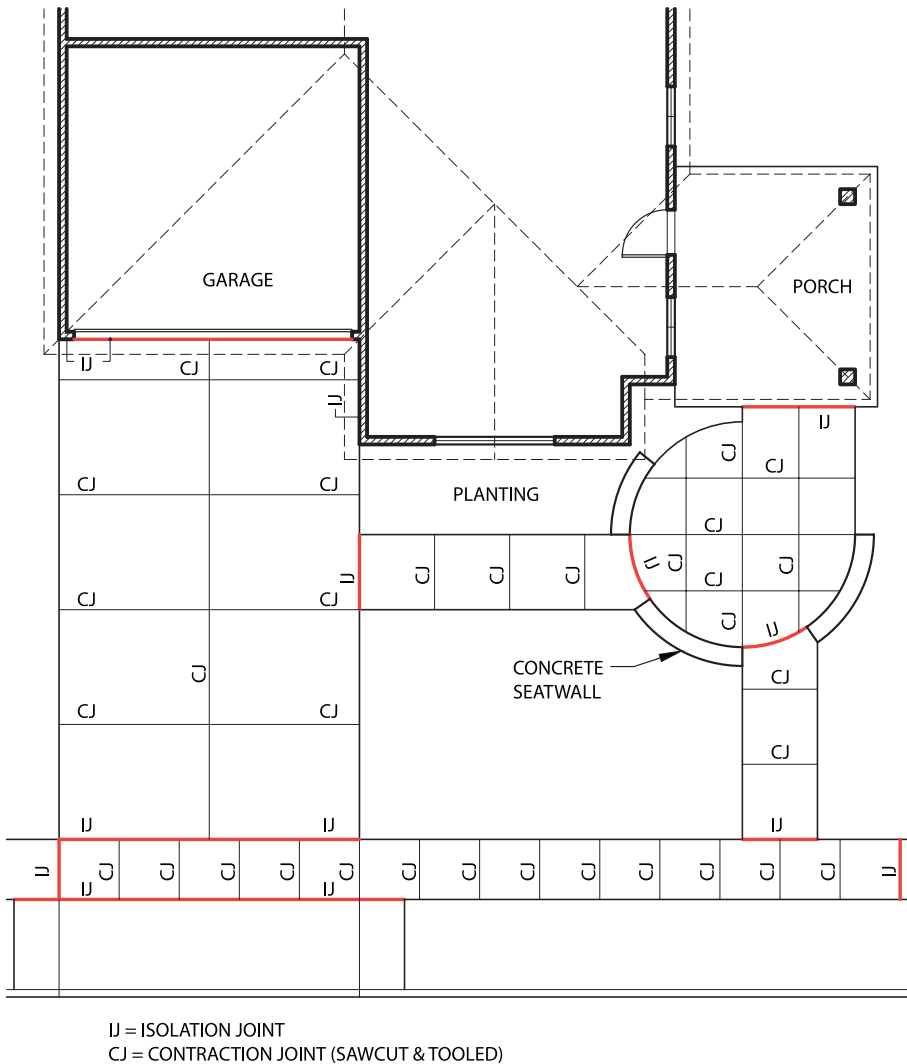


Fig. 4.6—Residential driveway and front entry jointing plan

(or tooled) to create equal panels and minimize shrinkage cracking. A $\frac{1}{4}$ in. (6 mm) thick isolation joint material is placed against the residence, seatwalls, driveway approach, and other vertical restraints prior to concrete placement. The top portion of this material will be removed after the concrete paving fields are placed and the void will be caulked. Steel dowels are placed between concrete placements at 24 in. (600 mm) on center to minimize vertical movement between the paving and banding.

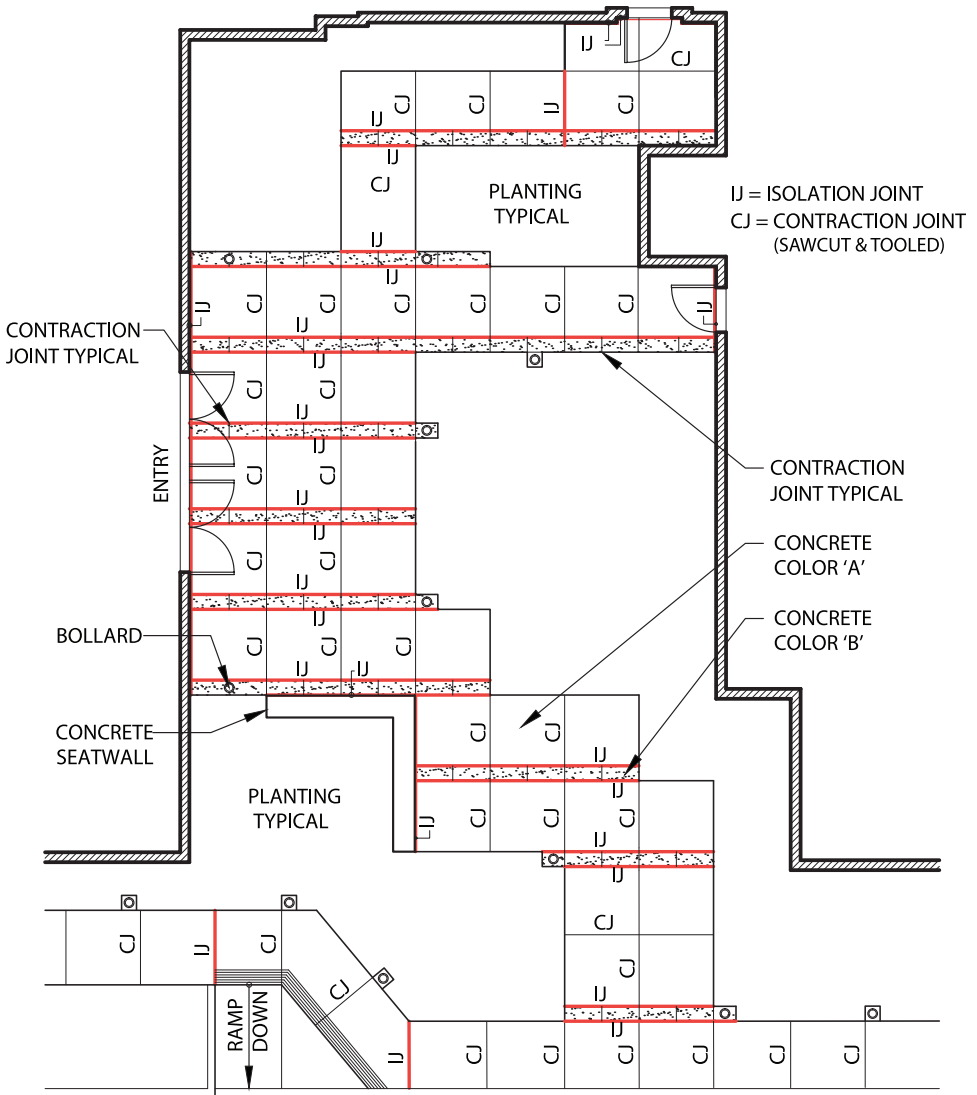


Fig. 4.7—Commercial project jointing plan

Commercial Project

An example of a joint layout for a commercial project is shown in Fig. 4.7. The concrete banding is placed first. The 12 in. (300 mm) wide bands are saw-cut (or tooled), to create contraction joints, at approximately 36 in. (0.9 m) on center. A ¼ in. (6 mm) thick isolation joint material is placed against the banding. The top portion of this material will be removed after the concrete paving fields are placed and the void will be caulked. Steel dowels are placed between the banding and

the paving at 24 in. (600 mm) on center to minimize vertical movement between the paving and banding.

Isolation joint material is placed against the building, seat-walls, curbs, and other vertical restraints prior to concrete placement. In this example, the concrete fields are saw-cut (or tooled) 6 ft (1.8 m) on center, or to create equal panels. This will help minimize shrinkage cracking. Contraction joints are always better than cracks.

Joints between Adjacent Concrete Placements

Isolation joints permit horizontal and vertical movement between the concrete paving and any walls, columns, vertical restraints, or adjacent concrete placements. Concrete shrinks as it cures. If the slab is rigidly joined to a fixed object, the slab is likely to crack because the drying shrinkage cannot be accommodated.

Isolation joint material, the full depth of the concrete paving edge, is placed between concrete placements and against walls, columns, and vertical restraints. Isolation joints can be composed of various materials, but decorative concrete contractors rarely use asphalt-impregnated fiber. Foam, with a perforated top for caulking purposes, is typically placed between concrete placements. The foam ranges from $\frac{1}{4}$ to $\frac{1}{2}$ in. (6 to 12.5 mm) thick. Refer to the following sections for a discussion of joint details.

Saw-cut Isolation Joint

In the sawcut isolation joint detail shown in Fig. 4.8, the concrete slab in Placement 1 is placed and edged using no more than a $\frac{1}{8}$ in. (3 mm) radius edger. Next, $\frac{1}{4}$ in. (6 mm) thick foam material is glued in place using spray glue. It is left 1 in. (25 mm) below the top of the concrete. It must be straight and flush with the face of Place-

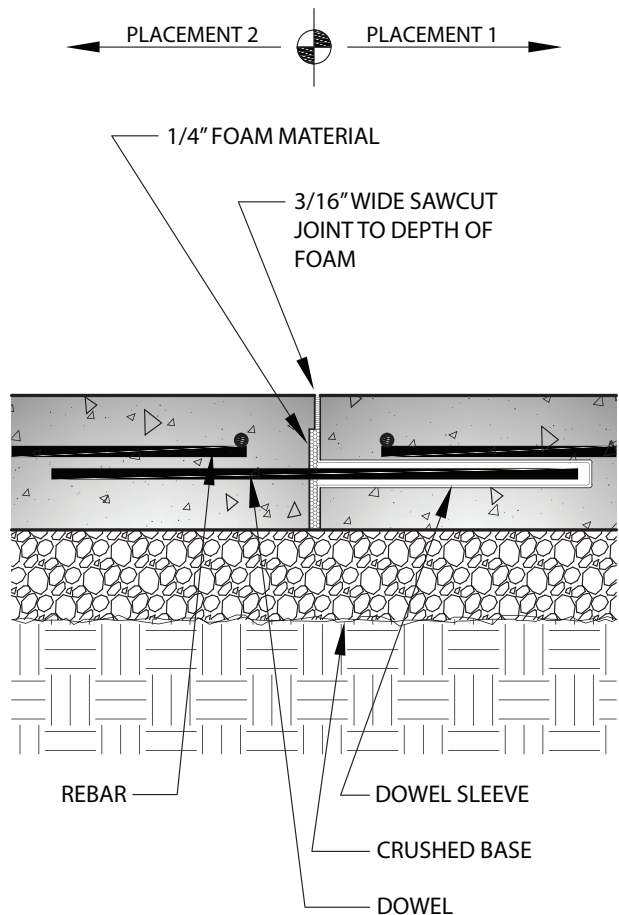


Fig. 4.8—Saw-cut isolation joint detail (Note: 1 in. = 25.4 mm)

ment 1. Concrete in Placement 2 is placed and finished over the top of the expansion joint material with a $\frac{1}{8}$ in. (3 mm) radius edger. The saw-cut joint, extending down into the foam, is sawed when the concrete has hardened sufficiently. The concrete in Placement 2 will be cantilevering over the foam. It is this section of concrete that must be cut out using a $\frac{3}{16}$ in. (5 mm) wide blade.

Isolation Joint with Joint Sealant

In the detail for an isolation joint with joint sealant shown in Fig. 4.9, the concrete slab in Placement 1 is placed and edged with a concrete edger per plans. If no edger is specified, a $\frac{1}{4}$ in. (6 mm) radius is recommended. Next, $\frac{1}{4}$ or $\frac{1}{2}$ in. (6 or 12.5 mm) thick foam material is glued in place using spray glue or nailed in place using concrete nails. The isolation joint material must be straight and flush with the face of Placement 1. Concrete in Placement 2 is placed against the foam expansion joint material. Care must be taken not to get any concrete behind the foam. If this does occur, it should be removed immediately using a margin trowel.

Saw-cut Construction Joint

In the detail for a saw-cut construction joint shown in Fig. 4.10, a saw cut is made where concrete placement has concluded for the day, usually conforming to a predetermined joint layout. This joint should receive dowels. Dowels permit horizontal movement, but little vertical movement. Doweled joints (Fig. 4.11) have generally replaced keyed joints, as keyed joints shrink and often fail under heavy loading conditions. In this detail, the two concrete paving sections are placed against one another and edged with a $\frac{1}{8}$ in. (3 mm) radius edger. Next, a saw cut is placed directly over the construction joint to remove a section of the concrete approximately $\frac{3}{16} \times 1$ in. deep (5 x 25 mm deep). This makes a more aesthetically pleasing construction joint that will tie into the adjacent saw-cut concrete paving.

Contraction Joints

To reduce the occurrence of random cracks, contraction joints are used to create straight-line planes of weakness in the slab. As the slab shrinks and tends to curl, the joints open slightly and cracks occur at the predetermined locations instead of randomly over the slab. Depth of tooled or saw-cut joints should be $\frac{1}{4}$ the slab thickness, T . The planes of weakness may be established by saw cuts after the concrete is finished and has hardened, or by using jointing tools to yield a joint similar to the tooled joint shown in Fig. 4.12.

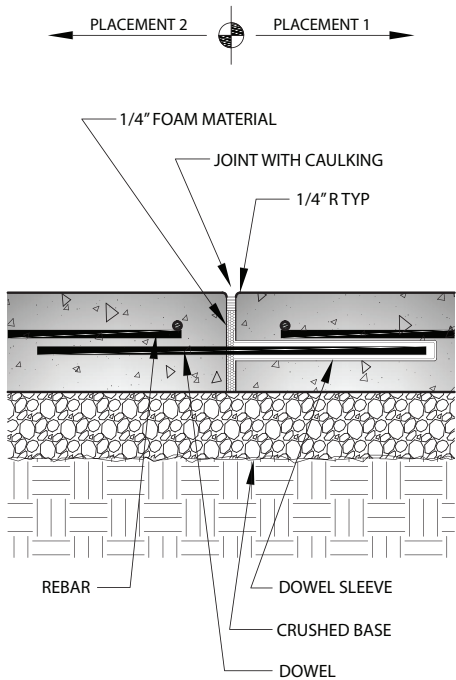


Fig. 4.9—Isolation joint with joint sealant detail (Note: 1 in. = 25.4 mm)

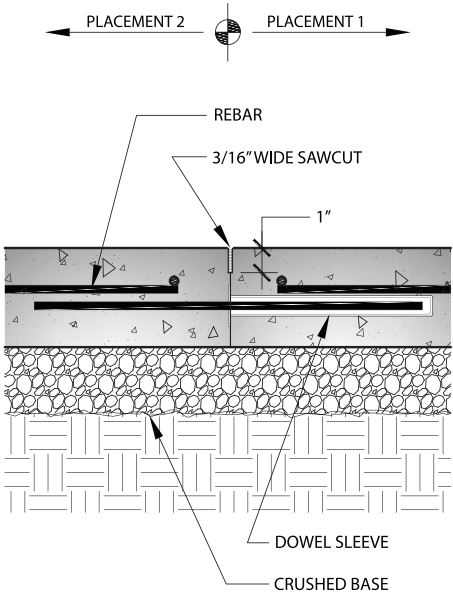


Fig. 4.10—Saw-cut construction joint detail (Note: 1 in. = 25.4 mm)



(a)



(b)

Fig. 4.11—Sleeves can be used to position dowels in concrete slabs: (a) a dowel sleeve in existing concrete; and (b) a steel dowel inserted through the isolation joint material into the dowel sleeve

Tooled Joints

Tooled joints require jointing tools manufactured with the specified radius and depth of groove. ACI 302.1R-04,¹ “Guide for Concrete Floor and Slab Construction,” recommends a 1/8 in. (3 mm) radius.

Saw-cut Joints

Saw-cut joints (Fig. 4.13) should be sawed as soon as the concrete is hard enough not to be torn or damaged by the blade, but before random cracks can form in the concrete slab. This requires sawing the slab from 4 to 24 hours after finishing is complete. The timing depends on air temperature, concrete mixture, thickness of the concrete slab, type of saw, and the substrate. Saw-cut joints at the earliest possible opportunity when a quality result can be provided.

REFERENCES

1. ACI Committee 302, “Guide for Concrete Floor and Slab Construction (ACI 302.1R-04),” American Concrete Institute, Farmington Hills, MI, 2004, 76 pp.

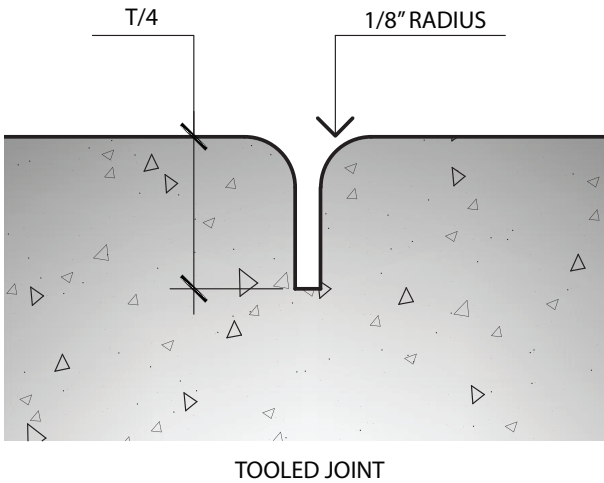


Fig. 4.12—A tooled joint (Note: 1 in. = 25.4 mm)

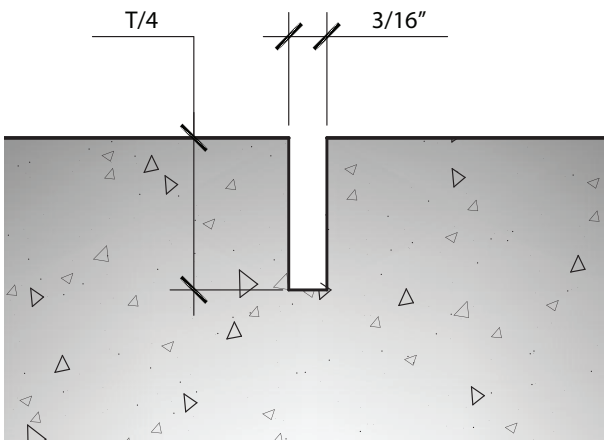


Fig. 4.13—A 3/16 in. (5 mm) wide saw-cut joint (Note: 1 in. = 25.4 mm)

CHAPTER 5: BASIC DECORATIVE CONCRETE COMPONENTS

Mixtures for Decorative Concrete

When ordering concrete for use in placing decorative concrete flatwork, you can specify several properties of both the materials used in the concrete and the concrete itself. These include:

- Nominal maximum size of the aggregate;
- Type of portland cement and other cementitious materials;
- Amount of cementitious material per cubic yard (cubic meter), or compressive strength;
- Air content for air-entrained concrete;
- Concrete slump;
- Type and amount of pigment for integrally colored concrete;
- Admixtures, such as shrinkage-reducing and water-reducing admixtures; and
- Type and amount of fibers.

Another approach to ordering concrete is to specify the performance properties of the concrete rather than the materials and proportions to be used. The two approaches, however, should not be mixed.

Nominal Maximum Size of Aggregate

The larger the nominal maximum aggregate size, the lower the water requirement to produce a given slump. Because higher water contents increase concrete shrinkage—and the possibility of random cracks—it's best to use as little water as possible in the concrete while still getting the needed slump. That means using the largest possible nominal maximum size aggregate. The most commonly used nominal maximum aggregate size for decorative concrete is $\frac{3}{4}$ in. (19 mm) aggregate. When tooled joints are required or stamped, concrete patterns exceed $\frac{1}{4}$ in. (6 mm) in depth; $\frac{3}{4}$ in. (19 mm) aggregate may be too large and concrete made with $\frac{1}{2}$ in. (13 mm) nominal maximum size aggregate will be needed. Finally, when the concrete will be pumped through small-line pumps with a hose diameter of 2 or 3 in. (50 or 75 mm), $\frac{3}{8}$ in. (9.5 mm) nominal maximum size aggregate or pea gravel may have to be used. Pea gravel mixtures that have high water-cementitious materials ratios are likely to shrink and crack more than concretes made with larger coarse aggregate; as a result, they can be problematic for decorative concrete work. Pumping concrete with larger aggregate sizes requires use of a more expensive 4 in.

(100 mm) diameter line, but the concrete quality will generally be better.

Concrete mixtures that contain 70% sand and 30% pea gravel are an example of concrete mixtures that will exhibit a large amount of shrinkage due to a relatively high water-cementitious materials ratio. Contractors often use such mixtures for ease of placement, but the durability and structural capacity of the concrete is compromised.

Portland Cement and Other Cementitious Materials

Portland cements are the most common cementitious materials used in decorative concrete. They are hydraulic cements, which means they set and harden by reacting with water, and they are not soluble in water after hardening. They come in several types, but the most commonly used in decorative concrete are Type I and Type II. Type I is a general-purpose portland cement suitable for all uses where the special properties of other types are not required. Type II portland cement has a moderate resistance to sulfate attack and is used when soils and ground water in contact with the concrete have higher concentrations of sulfate than normal but are not unusually severe. Type II cement is made with less of the compound that is attacked by sulfates, and it also puts off less heat when it reacts with water. Because of its increased availability, Type II cement is sometimes used for all concrete construction in an area, regardless of the need for sulfate resistance or moderate heat generation. Some cements may be labeled with more than one type designation, for example Type I/II or Type II/V. This simply means that such a cement meets the requirements of both cement Types I and II or Types II and V. Most cements are a shade of gray.

In areas with very high sulfate concentrations, Type V cement—which has a higher sulfate resistance than Type II cement—may be needed and should be used in concrete that also has a lower water-cementitious materials ratio, as shown in ACI 318-14,¹ Table 19.3.2.1. This will typically result in a higher-strength concrete than is normally used for decorative concrete work.

Some other cement options include using white cement or Type III cement. White cement combined with light-colored aggregates produces more intense colors for either integrally colored concrete or concrete colored with dry shakes. Type III cement produces higher early strengths and is especially useful in cold-weather concrete placing. Type III or white cements cost more than Type I cement.