Chapter 7: Bridge Deck Construction

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7-1 Introduction

This chapter updates and replaces Structure Construction's (SC) *Bridge Deck Construction Manual*, first published in 1991 and updated in 2015.

Bridge decks are often considered the most critical element of a bridge. They are subject to complex loading and various environmental conditions. They must not only be structurally sound but also meet specific performance criteria to ensure a smooth and safe ride, especially for high-speed traffic, as they are the bridge element that most directly affects the traveling public. The service life and maintenance costs of a bridge are most closely linked to the quality of its deck. Attention to detail, combined with sound engineering and construction practices, will help achieve a bridge deck that provides exceptional drivability and increased durability throughout its lifespan.

Contract Specifications, Section 51-1.03D, *Concrete Structures – General – Construction – Placing Concrete,* requires that the deck be poured separately from the girder stems. This prevents construction stresses such as shrinkage and falsework settlements from being incorporated into the deck, which can lead to premature cracking and deterioration.

7-2 Bridge Deck Preconstruction Planning

Chapter 2, *Preconstruction Planning,* emphasizes the importance of planning and preparation for construction of reinforced concrete structures. The following subsections outline additional steps for preparing specifically for the construction of bridge decks. The subsequent sections of this chapter, along with the other chapters of this manual, provide further details on the items mentioned below.

7-2.01 Construction Details

Thoroughly and carefully review the contract documents and relevant submittals, paying particular attention to the following aspects related to bridge deck construction:

1. Skew, camber, strike-off devices, and screed rail (rails for the surface finishing machine) grade.
2. Horizontal curves, and any varying deck widths.
3. Super-elevation including any transitions.
4. Interaction between bent cap and bridge deck bar reinforcement (bent caps typically have large diameter bar reinforcement that are placed underneath the deck reinforcing, and poured together with the deck concrete).
5. Openings through deck and clearance around bent cap steel.
6. Hinges, prestressing hardware, and their relationship with deck grades.

7. Deck grading for steel girder bridges.
8. Precast prestressed (PC PS) concrete girders and slabs, particularly deck grades and thickness adjustments for uneven cambers and cross slopes.
9. Variable span lengths and non-parallel abutments or bents.
10. Stem and diaphragm stirrup hook placement and resulting effect on placement of deck bar reinforcement.
11. Longitudinal and transverse construction joints.
12. Paving notch details.
13. Sidewalk and barrier rail bar reinforcement layout and height, including the effects of superelevation (cross slope) and planned deck overlays.
14. Lane line locations relative to required longitudinal construction joints and planned closure pours.
15. Utilities, drains, etc.
16. Block-outs in the deck for prestress duct vents
17. Traffic impact bars hooked into the abutment diaphragms.
18. Deck reinforcement clearance at locations likely to require a profile grind, including across joints, hinges, and planned transverse construction joints.
19. Additional deck thickness if grinding and grooving is Contractor's selected means and method for meeting friction and sound requirements.

7-2.02 Deck Placement Work Plan and Preconstruction Meeting

Because the deck is the final element in the bridge superstructure to be constructed, deck construction must be coordinated with - depending on the bridge type - the construction of the stem and soffit or the fabrication and erection of the PC/PS concrete girders and slabs. SC staff must thoroughly understand the Contractor's proposed bridge deck construction methods and confirm they comply with the contract requirements. Review and authorize the Contractor's deck placement work plan per *Contract Specification*s, Section 51-1.01C(1), *Concrete Structures – General – Submittals – General,* and Chapter 2, *Preconstruction Planning*.

Schedule a deck placement preconstruction meeting with the Contractor before scheduled deck pours. In addition to discussing structural concrete QC per *Contract Specifications*, Section 90-1.01D(9), *Concrete – General – Quality Assurance – Preconstruction Meeting for Cast-In-Place Structural Concrete Members*, this meeting offers an opportunity to identify and address any potential issues that may have been overlooked or ones that may have developed since the deck placement work plan was authorized.

While the specifications do not explicitly list the required items for the deck placement work plan, the following subsections highlight key considerations to review when assessing the plan. These points should also be addressed during the bridge deck placement preconstruction meeting. Detailed guidance on these topics can be found throughout this manual, with specific references to bridge deck construction in subsequent sections of this chapter.

7-2.02A Sequence and Limit of Placement

Address the following questions as they pertain to the deck pour sequence and placement:

1. Are specific concrete placement sequences outlined in the contract documents or in the authorized falsework shop drawing?
2. How will the Contractor manage screed rail grades on projects with challenges such as varying deck widths, multiple pours, and screed rail supports buried on girder stems, etc.?
3. Will the Contractor need to place any longitudinal or transverse construction joints not indicated in the project plans? (Standard Plan B0-5, *Bridge Details.*)
4. Are longitudinal construction joints located at or near a lane line?
5. Is stage construction required or being proposed by the Contractor?
6. Are there any time-dependent hinge behaviors that need to be addressed?
7. What quantity of concrete is required for the pour(s)?
8. Will placement interfere with public traffic, existing power lines, or other obstructions?
9. What direction is the pour(s)?
10. Are closure pours planned? If so, how will they be formed, poured, and stripped and have the related bar reinforcement details been addressed?
11. When is falsework release scheduled, and does this timeline comply with the contract requirements?

7-2.02B Location of Screed Rails and Construction Joints

The proper placement of screed rails and construction joints is critical. Address the following details:

1. Potential locations of rail supports for the bridge deck finishing machine:
    a. At the edge of deck.
    b. At longitudinal construction joints.
    c. At exterior or intermediate girder locations (it is best practice to locate screed rail supports at the bridge girder).

2. Details for longitudinal construction joints – Refer to Standard Plan B0-5, *Bridge Details*.
3. Evaluation of screed rail support system – Assess the deflection, rotation, and overall stability of the system.
4. Adjusting and checking screed rail elevations – Understand the methods required to achieve correct screed rail elevations which will produce the desired deck elevations, deck thickness, and smooth profile.
5. Grade control at construction joints – Understand the methods necessary to maintain proper grade at longitudinal and transverse construction joints.
6. Stability of bulkheads for construction joints – Discuss the measures to ensure the stability of bulkheads during construction.

7-2.02C Concrete Conveyance, Placement Method, and Rate

Discuss the following regarding the length and timing of haul from batch plant to delivery point, and from delivery point to final placement:

1. Can the concrete be delivered at a consistent, uniform rate (i.e., time between each concrete truck delivery)?
2. Will the delivery, placement, and finishing of concrete pose any safety hazards to the public?
3. What method will be used to place the concrete on the deck after delivery (e.g., pump, tailgate, bucket and crane, slick line, etc.)?
4. Does the placement method require additional support considerations for the formwork or bar reinforcement?
5. What is the anticipated rate of placement? Is this rate consistent with the delivery rate, and how will it impact the surface finishing process?
6. How will the concrete be properly consolidated after placement? How many vibrator crew members are required to accomplish proper consolidation?
7. What slump and range is specified for the concrete mix? How will the slump affect the placement method (e.g., pumping) or the finishing machine's ability to properly finish the concrete? (Refer to *Contract Specifications*, Sections 90-1.02A, *Concrete – General – Materials – General,* and 90-1.02G(6), *Concrete – General – Materials – Mixing and Transporting Concrete – Quantity of Water and Penetration or Slump)*
8. Could the conveyance and placement be interrupted for any reason (e.g., moving the pump truck, crane, or finishing equipment)? What provisions are in place to keep the concrete fresh during interruptions?
9. Will the placement method cause segregation or result in a non-uniform or uneven pour front?

10. What measures are in place to comply with *Contract Specifications*, Section 13-9, *Water Pollution Control – Temporary Concrete Washouts*? Ensure the Contractor provides the required concrete washout submittal within the required timeframe.
11. For decks requiring pumping from multiple locations, will pumps be in place ahead of the hand-off, or will placement need to stop while pumps relocate? Are these transitions supported by the truck spacing/timing?

7-2.02D Finishing Roadway Surfaces

Consider the following roadway finishing topics:

1. The Contractor is responsible for the finishing process, as outlined in the following *Contract Specifications*:
   a. Section 51-1.03F(5), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Roadway Surfaces*
   b. Section 51-1.03F(6), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Pedestrian Overcrossing Surfaces.*
2. Deck Surface Acceptance Criteria – The resulting bridge deck surface must meet several criteria:
   a. Longitudinal Texture – Provided using acceptable tining or grooving methods.
   b. Smoothness and Rideability – Assessed using a profilograph.
   c. Friction – Coefficient of friction verified via skid testing.
   d. Surface Crack Intensity – Number and size of cracks within a defined area must not exceed specified limits.
3. SC Staff's Responsibility – SC staff is responsible for establishing elevation control points.
4. Special Finishing Considerations – The following factors require special attention during finishing:
   a. Lightweight Concrete – Its tendency to be more porous than typical concrete can lead to an uneven finish.
   b. Adverse Weather Conditions – Pouring during inclement weather, including heat, wind, cold, rain, etc., can negatively impact the quality of surface finish.
   c. Deck Overlays – Techniques for achieving required finish may be different than for typical concrete deck pours.
   d. Shrinkage Reducing Admixtures and Polymer Fibers – Consider their potential effects on the concrete properties. Concrete workability may be affected if not mixed properly.
   e. Superelevation and its effect on concrete placement, allowable slump, and impact to curing operations.

7-2.02E Finishing Crew and Operators

The Contractor determines the size and classification of the crew. Staffing for a concrete bridge deck pour is an important topic to discuss with the Contractor, as it directly impacts both the time required to complete the deck pour and the overall quality of the work.

While the degree of mechanization and the skills of individual laborers may vary from project to project, Table 7-1 provides a suggested average crew size for a typical 2-lane bridge deck. Labor type may be interchangeable:

Table 7-1. Finishing Crew and Operators

Number of Positions	Duties
1	Foreman who oversees the concrete pour
2	Laborers to rake ahead of the deck finishing machine
1	Operator of the deck finishing machine
2	Finishers for edging
1	Broom and cure laborer
2	Crew members operating vibrators
1	Bridge carpenter to monitor the falsework on slab bridge pours and overhang supports for large and heavy overhangs
1	Laborer tending concrete truck

7-2.02F Special Equipment and Material

Discuss the potential need for special or additional equipment and material for bridge deck concrete pours:

1. Cooling of Concrete in Hot Weather Conditions (*Contract Specifications*, Section 90-1.02G(2), *Concrete – General – Materials – Mixing and Transporting Concrete – Machine Mixing)*:
    a. Use of an ice machine at the plant or chilled water.
    b. Employ fogging systems or sprinklers over the coarse aggregate stockpiles.
    c. Provide shade cover over the aggregate stockpiles.
    d. Ensure a cool water supply at deck pour.
    e. Fogging rebar and forms with cool water ahead of placement. Be cautious of over-watering, to avoid runoff which pools at falsework supports or causes erosion and storm water discharges.

2. Critical Back-Up Equipment and Machinery – Good practice is to provide the availability of backup machinery and essential spare parts, including pumps, light plants, generators, vibrators, etc., to minimize operational disruptions.
3. Heating and Protecting Concrete in Cold Weather:
    a. Heated water for mixing.
    b. Heating coarse aggregate as needed.
    c. Cover aggregate stockpiles with black polyethylene sheeting (Visqueen).
    d. Protect completed deck as required to maintain temperature requirements, as specified in *Contract Specifications,* Section 51-1.03I, *Concrete Structures – General – Construction – Protecting Concrete Structures*. (Based on SC experience, deck curing temperatures have been kept over 60° F, even in freezing conditions, by using Burlene or carpets on the deck, followed by black polyethylene sheeting, followed by additional carpets.)
4. Rain Precautions – The Contractor should avoid scheduling concrete deck placements during anticipated inclement weather. If there is a chance of rain, they must take precautionary measures and ensure necessary materials are readily available at the site, such as:
    a. Polyethylene sheeting (Visqueen) for covering.
    b. A method of placing and removing polyethylene sheeting efficiently.
    c. A plan to remove excess water from the low side of deck.
    d. Provisions for building a bulkhead (usually metal or wooden) with additional bar reinforcement, if required by SC staff, for an emergency construction joint.

7-2.02G Curing Equipment

Address the following considerations regarding curing methods:

1. Water Supply at the Site – Verify an adequate water supply is available to the Contractor.
2. Sufficient Supply and Pressure – The system must provide enough water pressure to produce a fog mist for curing.
3. Atomizing (Fog) Nozzle – The nozzle must be adequate to evenly distribute water as a mist.
4. Water Quality – The water used for curing and in deck construction must meet the requirements of *Contract Specifications*, Section 90-1.02D, *Concrete – General – Materials – Water*.
5. Curing Blankets – Adequate supply of Burlene or other cure blankets for the deck area must be provided.

6. Identification of Curing Compounds – Different types of curing compounds must be kept separate and clearly identifiable to avoid confusion during application. Shelf life of curing compound.
7. Securing Curing Blankets – Measures must be taken to prevent curing blankets from being displaced by strong winds. In addition to the weight of any cure water, contractors should consider using additional methods, such as placing 2-inch nominal lumber along the edges of the blankets at edges.
8. Curing Water Application – Determine whether water will be applied continuously or if blankets or carpets will be watered on a regular schedule during the initial 7-day water cure.
9. Application of Curing Compound After Initial 7-day Water Cure (*Contract Specifications*, Section 90-1.03B(3), *Concrete – General – Construction – Curing Concrete – Curing Compound Method*):
   a. The Contractor must demonstrate the adequacy of the curing compound application system before applying. The method must employ the use of power-operated spraying equipment with an operational pressure gauge.
   b. The use of conventional hand pump garden sprayers, including Hudson-type spray cans, is **not permitted** for applying deck curing compound.
10. Curing Compound Hose Lines – Check that there are no leaks in the curing compound hose lines.
11. Are staff scheduled to monitor ongoing curing operations which span across non-working days and weekends?

7-2.02H Construction Conditions and Safety

Address the following construction conditions and safety precautions:

1. Fall Protection – Ensure proper installation of rails and toeboards at the edge of the deck and any elevated temporary work platforms in accordance with Cal/OSHA Construction Safety Orders (CSO) §1620, *Design and Construction of Railings* & §1621, *Railings and Toeboards*. If installation of railings poses a safety risk, use of controlled access zones per CSO §1671.2, *Controlled Access Zones and Safety Monitoring Systems* may be considered.
2. Avoid Equipment Interference with Overhead Lines – Do not allow the placement or operation of equipment that will interfere with overhead power or utility lines. Advanced planning is required, and depending on proximity and line voltage, the utility owner may provide a spotter to monitor concrete placement near power lines.
3. Impact of Concrete Delivery on the Public – Assess whether the delivery of concrete will adversely affect the public or if there is a risk of interruptions to the placement process.

4. Bridge Deck Finishing Machine Placement – Ensure that the location of the bridge deck finishing machine does not interfere with the handrails. Handrails should remain intact throughout the process. Sufficient runoff length should be provided to ensure the finishing equipment can be run beyond the pour limits.
5. Walkways for Foot Traffic – Check that walkways designated for foot traffic are not less than 20 inches wide, as specified in Cal/OSHA CSO, § 1624, *Runways For Foot Traffic*.
6. Eye-Wash Stations – Verify that eye-wash stations are properly placed and spaced in accordance with Cal/OSHA General Industry Safety Orders (GISO) § 5162, *Emergency Eyewash and Shower Equipment*.
7. Nightwork – Sufficient lighting should be setup before shift and proper reflective PPE worn by all persons on site.

7-3 Bridge Deck Forms

Constructing a bridge deck that is structurally sound and durable requires thorough planning and preparation, beginning with the construction of the formwork for bridge decks. While Chapter 3, *Forms*, provides a general overview of formwork construction and inspection, the following section focuses on formwork specifics for bridge deck construction.

7-3.01 Types of Form Details

The bridge superstructure dictates the Contractor's method for supporting the cast-in-place (CIP) concrete deck forms. The forming systems typically fall into two categories:

1. Stay-in-place forms
2. Exposed surface forms.

7-3.01A Stay-In-Place Forms

Stay-in-place forms are concrete forming systems that usually are not required to be removed, or stripped, after the concrete structure has been poured unless specified otherwise. Rather, these forms can be left permanently in place.

The most common stay-in-place forming system is the lost deck form system. It is used to construct the deck of cast-in-place (CIP) box girder bridges, usually for the interior portion of the deck above the bridge cells. Formwork used inside the bridge cells will typically remain inside of the cell after the deck concrete is poured. There are various methods for lost deck design and construction. Figure 7-1 shows a general detail for lost deck that is commonly used by contractors, and Figure 7-2 and 7-3 are construction photos illustrating that lost deck form detail.

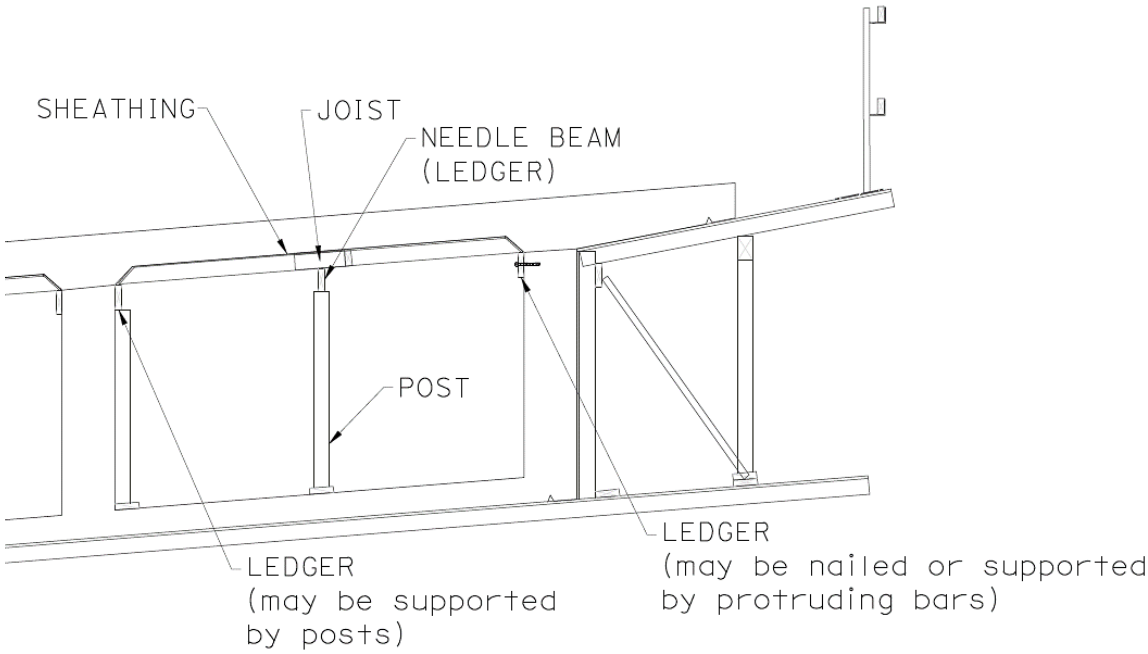

Figure 7-1. Lost Deck Detail

Figure 7-2. Ledger Support for Lost Deck Forms

Figure 7-3. Typical Deck Sheathing and Supports on a CIP Box Girder Bridge

For typical CIP bridge structures, the lost deck forms that support the bridge deck concrete are usually comprised of the following:

1. Sheathing – Forming material in direct contact with concrete.
2. Joists – Horizontal members that distribute loads from sheathing.
3. Ledgers – Support for a set of joists, typically at their ends and sometimes intermediate points (the latter may also be called a “stringer”).
4. Needle beams – Midspan support line that serves to reduce the span of the joists (may also be labeled as “ledger” in shop drawings).
5. Posts – Support for ledgers and other formwork pieces mentioned above.

Sheathing can be made of the following:

- Plywood, interior or exterior grade
- Oriented strand board (OSB)
- Other adequate board.

Sheathing must be mortar-tight with holes patched as required. The sheathing sits atop the joists which are generally 4-by-4-inch or 2-by-4-inch material. A useful note about OSB – although some experienced carpenters are unaware of it, the OSB has a “strong” direction; refer to the stamp on the sheathing and look for details and notes on the lost deck portion of the authorized falsework plans, that may require a certain orientation.

Ledgers support the joists and are typically supported by posts or short dowel bars cast into, and protruding from, the girder stem. They may also be attached directly to the girder face using low velocity powder driven nails.

Although lost deck is typically intended to remain in place, there are situations when the forms and materials must be removed. For example, if utility facilities are to be installed within the bridge cells or if bridge cells will have permanent access, the deck forms within those forms must be removed. Refer to *Contract Specifications*, Section 51-1.03C(2)(b), *Concrete Structures – General – Construction – Preparation – Forms – Removing Forms,* for additional situations when removal is required, including guidelines as to what extent the forms must be removed.

For precast or steel girder bridges, stay-in-place deck forms are sometimes used in locations where:

- The removal of the forming would be difficult or disruptive to the public.
- The removal of forms would cause an unacceptable delay to the completion of the project, possibly adding a season to the work.
- Unacceptable environmental impacts would result, if forms were removed.

Stay-In-Place Precast Concrete Deck Panels (PDP) are a specific type of stay-in-place form system specified for projects with precast concrete girder superstructures. PDPs are partial-depth precast, pretensioned concrete deck panels that span between girders. The panels are designed for multiple purposes: first, to act as forms for the remainder of the deck concrete to be cast above, and as a composite deck structure when the CIP portion gains strength. Structure Technical Policy, STP 9.1, *Stay-in-Place Precast Prestressed Concrete Deck Panels for Precast Concrete Girder Superstructures* details the policy for the inclusion of PDPs on projects.

Permanent Steel Deck Forms (PSDF) are another stay-in-place form system that has been used to form bridge decks. This system may either be specified for a project, or its use proposed by contractors. Refer to Chapter 3 for further details regarding PSDF.

7-3.01B Exposed Surface Forms

Exposed surfaces are concrete surfaces that will be visible; thus, as mentioned in Section 3-3, *Forming System* of this manual, plywood must at least meet the requirements for U.S. Product Standard PS 1 for Exterior B-B (Concrete Form) Class I Plywood, as required per *Contract Specifications*, Section 51-1.03C(2)(a), *Concrete Structures – General – Construction – Preparation – Forms – General,* and Section

51-1.03F(2), *Concrete Structures – General – Construction – Finishing Concrete – Ordinary Surface Finish*. Additionally, the forms for these surfaces must be removed in accordance with *Contract Specifications*, Section 51-1.03C(2)(b), *Removing Forms*. Exposed surfaces of CIP bridges include:

1. Edge of the deck.
2. Soffits of concrete box girder and slab bridges.
3. Deck soffits for T-beam, steel girder, precast concrete girder bridges.
4. Deck overhangs (projection of the deck that overhangs the exterior girder) for all bridge types.

For slab bridges, the plywood soffit forms are directly attached to and supported by the falsework joists or stringers, making them an integral part of the falsework. Deck slab forms for T-beam bridges, steel and precast concrete girder bridges, and deck overhangs may be made of conventional joist and plywood construction. Figures 7-4, 7-5, and 7-6 are examples of a slab bridge, a steel girder bridge, and a T-beam bridge, respectively. These bridge types typically require their deck forms be removed, unless otherwise specified.

Figure 7-4. Example of a Slab Bridge (Mojave River Bridge, Br No. 54 0278L)

Figure 7-5. Example of a Steel Girder Bridge (Pfeiffer Canyon Bridge, Br No. 44 0298)

Figure 7-6. Example of a T-Beam Bridge (Newton Road UC, Br No. 04 0125)

Figure 7-7 shows a general detail for overhang formwork that may be used by contractors for CIP box girder bridges. Edge of deck forms, which set the placement limit for the deck concrete, are typically installed above the overhang posts. Overhang posts are supported on the falsework.

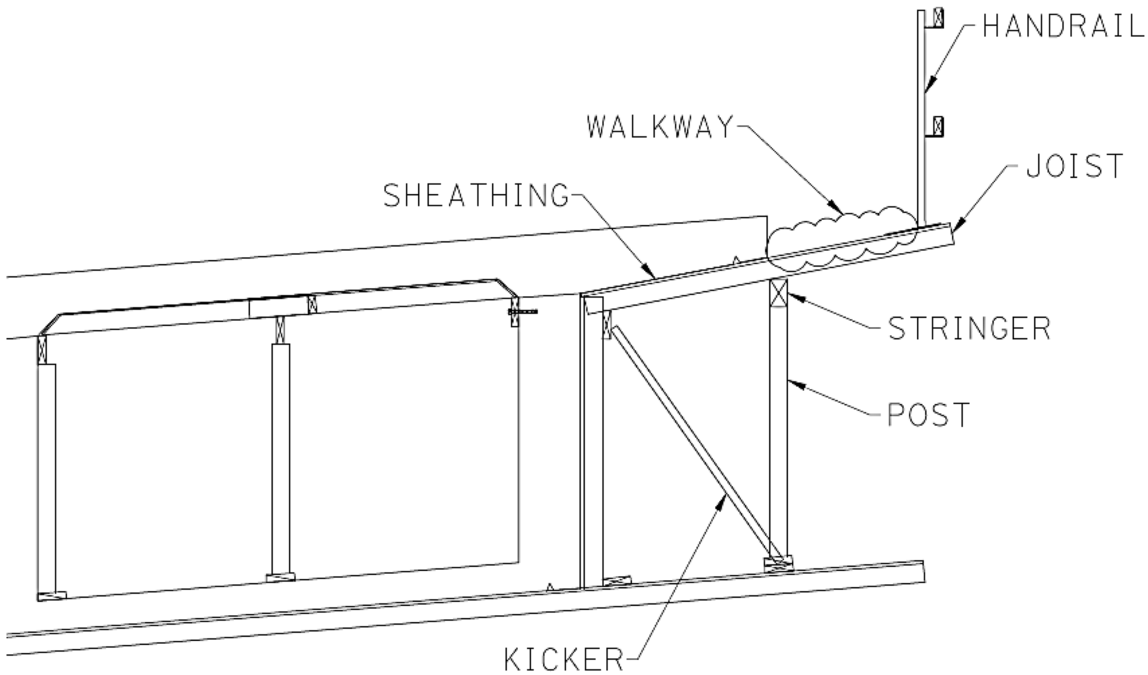

Figure 7-7. Overhang Formwork Detail

Construction of deck and deck overhangs on steel and precast concrete girder bridges, as well as reconstruction of deck overhangs on existing bridges, typically incorporate manufactured products like brackets to support the overhang formwork. Additionally, interior deck forms for steel and concrete girder bridges may utilize manufactured brackets. Figures 7-8 and 7-9 are details of deck formwork for a precast concrete girder bridge.

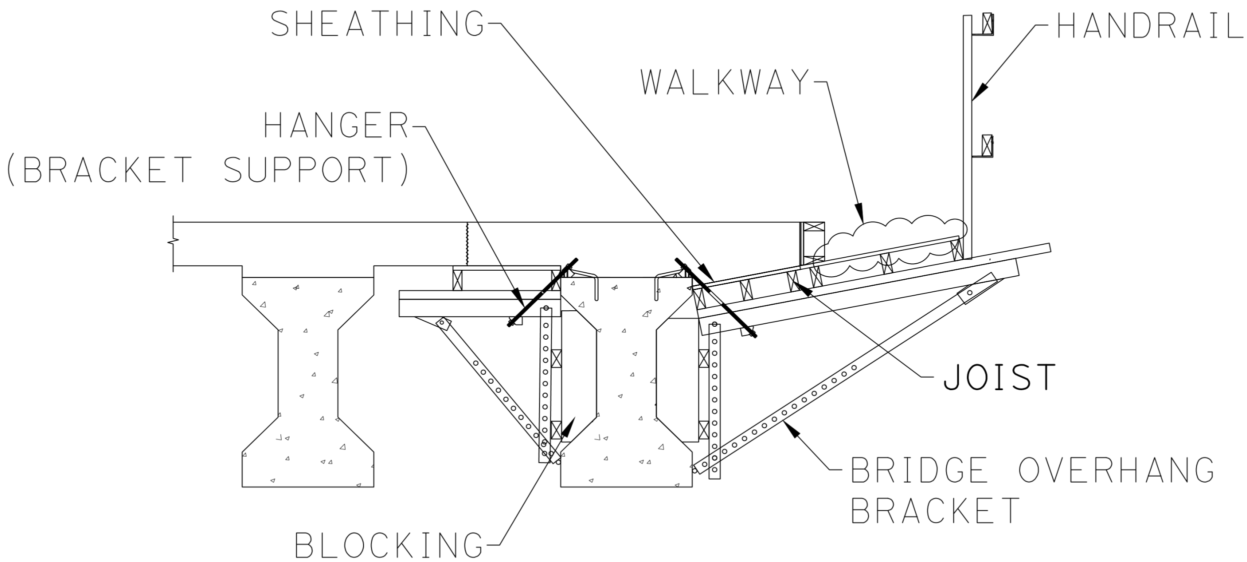

Figure 7-8. Precast Concrete Girder Overhang Formwork Detail

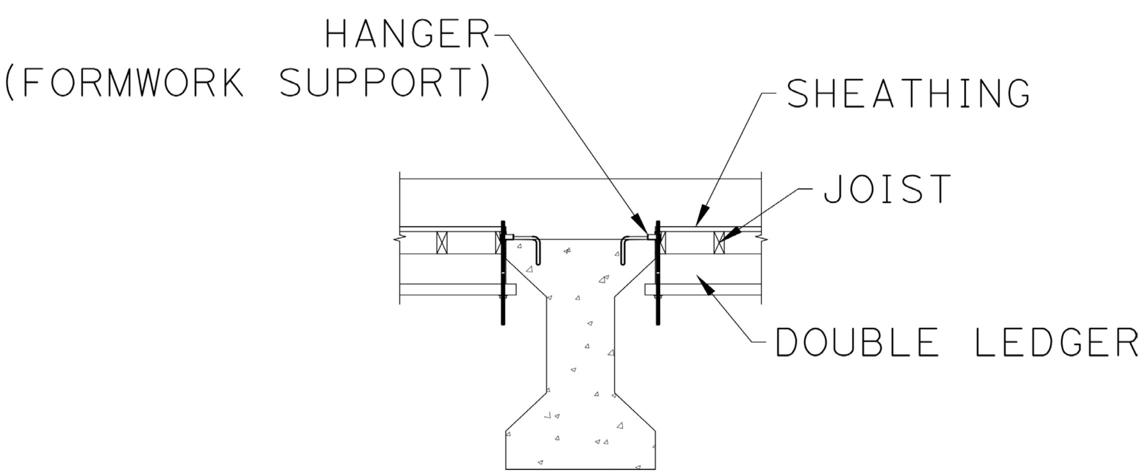

Figure 7-9. Precast Concrete Girder Deck Formwork Detail

7-3.02 Structural Adequacy and Deflection

Contract Specifications, Section 48-2.02B(1), *Temporary Structures – Falsework – Materials – Design Criteria – General,* states that bridge deck forming systems, including lost deck and overhang formwork, must be considered and designed as falsework. Perform an independent engineering analysis to verify the forming system is structurally adequate and complies with the contract requirements. The Structure Construction (SC) *Falsework Manual* provides detailed guidance on the analysis required when reviewing and authorizing the design of a concrete bridge deck forming system, including for deck forming systems that use timber and manufactured products, such as overhang brackets.

In addition to the requirements of *Contract Specifications*, Section 48-2, *Temporary Structures – Falsework*, the design and construction of deck forms for steel girder bridges are governed by *Contract Specifications*, Section 55-1.03B, *Steel Structures – General – Construction – Falsework*. These contract requirements reduce the potential for damage and distortion/deflection of the girders and new deck.

Form deflection and settlement usually occur during and after concrete placement. This movement is generally not structurally detrimental to the deck slab, provided that the deflection does not continue after the initial set. If deflection does continue, it could result in an irregular deck profile surface and may lead to cracking. The same can also result if forms deflect more than anticipated.

When screed rails are located in the overhang area, deflection must be minimal for appearance and satisfactory grade control. Accurately determining deflection is difficult, particularly when brackets or jacks with cantilevered joists or outriggers are used.

7-4 Bridge Deck Formwork Construction

Proper bridge deck formwork construction plays a major role in achieving an acceptable bridge deck. Preconstruction planning is critical for constructing the bridge deck to correct alignment and profile. The Contractor must determine and propose a deck forming system, the types of material to use, where screed rails will be located (for example, on the edge of deck forms), and how they will be adjusted. Discuss survey and grade control requirements and procedures with the Contractor, starting at the preconstruction meeting and continuing throughout the process.

7-4.01 Form Alignment

The Contractor positions and aligns the bridge overhang formwork based on the theoretical location of the deck, specifically its edges. These lines are known as the “edge of deck” (EOD) lines. SC staff usually provides edge of deck survey control points for the Contractor’s use to lay out edge of deck lines, which SC staff subsequently verifies. For typical construction of new CIP box girder bridges, edge of deck lines are laid out first on the soffit forms. The Contractor then lays out the exterior and interior bridge girders.

The edge of deck layout can be performed using a transit, total station, or stringline. Edge of deck on horizontal curves can generally be established with stringline using simple survey techniques such as the chord offset method. As the horizontal radius becomes small (a ‘tight’ curve), more accurate calculations may be warranted, or the chord distances shortened to maintain a close approximation. District surveyors may be able to assist with edge of deck layout for bridges with complex geometry.

Edge of deck layout is also needed on top of the overhang forms for setting edge of deck forms, or bulkhead; however, for most bridges, the overhang distance is a constant dimension relative to the exterior girder, so establishing EOD may be simplified. Before setting the layout line for the edge of deck forms, the Contractor must roughly set the overhang forms to planned elevation. The Contractor can accomplish this rough grading with the use of templates or the lost deck grade dowels, the latter which will be discussed in the following sections.

No matter what method of establishing line is used, always check the following:

1. Verify both edges of deck plane into known points at each end of the structure.
2. Verify the overall deck width at several locations throughout the length of the structure, considering bridge cross slope (refer to Section 2-2.01 of this manual), especially at key locations like the beginning and end of superelevation transition zones, at hinges, and at all deck joint locations.

7-4.02 Formwork and Bridge Deck Elevation

The elevations that bridge deck forms are set to, including overhang forms, are controlled by the theoretical deck grades, with consideration given to designed long-term bridge camber, calculated short-term falsework deflection, and anticipated falsework deflection. Per *Contract Specifications*, Section 51-1.03F(5)(a), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Roadway Surfaces – General*, the Department is responsible for providing elevation control in the field for the Contractor to construct the bridge deck. Accounting for the known deck thickness, the Contractor can set deck forms to the proper elevations.

7-4.02A Deck Elevation Control Points

Before the stem and soffit pour, plan where deck elevation control points should be placed on the bridge. Deck elevation control points are typically established in pairs, one on each exterior girder. Wide bridge decks or ones with a crown may require an additional control point at an interior girder. Mark their locations on the deck contour plots, or 4-scales, to create a set of grid grades along the bridge girders so that a plane can be established for the deck. This can also be performed using CAD software if using an electronic version of the bridge deck contours.

Per *Contract Specifications*, Section 51-1.03F(5) – *Concrete Structures – General - Construction – Finishing Concrete – Finishing Roadway Surfaces*, provide deck elevation control points at all breaks in the grade and intervals not closer than 8 feet longitudinally and 24 feet transversely to the centerline of bridge. A typical longitudinal distance between deck elevation control points is approximately 10 feet along the bridge centerline, evenly spaced within the span. Common practice is to have the first and last control point within a bridge span be 1 foot from the faces of end diaphragms and bents, then establish the spacing in between as described previously. If the deck is on a horizontal curve, the spacing of the control points will be larger on the outer girder compared to the inner girder.

If deck grading will be complicated, additional control points may be necessary. Discuss deck elevation control point layout with the Contractor in advance. Consider the amount of vertical curve and camber when determining these intervals so that both short-term camber and long-term bridge camber and vertical curve profile are accounted for. When using the deck contours to pick theoretical grades, recall that the vertical curve is captured thereon, while the design bridge camber is not.

Next, draw the design bridge camber from the “Camber Diagram”, located in the project plans, onto the deck contour plots. Design camber for the decks of conventionally reinforced concrete box girder, T-beam, and slab bridges is the sum of the anticipated long-term deflection due to concrete creep and the initial dead-load deflection of the superstructure. This camber is built into the initial deck grades to help counteract the eventual long-term bridge deflection. Long-term deflection of conventionally reinforced concrete bridges can continue for about four years. Approximately 25 percent of the total deflection occurs immediately after falsework is removed.

Then determine if falsework settlement or deflection needs to be considered. Experience shows that for box girder and T-beam structures, essentially all the falsework deflection occurs when the soffit and/or girders are poured. For post-tensioned bridges with long falsework spans, studies indicate that 50 percent or less of the theoretical deflection due to the deck slab dead load is realized when the deck is poured. Similarly, most of the falsework settlement occurs during the placement of the stem and soffit concrete. Therefore, the deck camber for conventional reinforced or post-tensioned box girder and T-beam structures would normally not include falsework settlement or deflection; however, assess the potential for deflection on a case-by-case basis, accounting for variables such as structure type, weight, falsework span length, etc. For instance, in the event of long falsework spans, it may be appropriate to include a small allowance for settlement. Note that this reduction in dead load of the deck is applicable only for determining falsework settlement and deflection. It is not applicable when determining dead loads to be used for formwork or falsework design. Refer to *Contract Specifications*, Section 48-2.02B(2), *Temporary Structures – Falsework – Materials – Design Criteria – Loads,* and the *Falsework Manual* for additional guidance regarding the calculations of dead loads for falsework.

Lastly, calculate and record the bridge deck elevations for each of the deck elevation control points. This is done by adding the following values for each of the control points:

1. Contour (deck) elevation
2. Design bridge camber value
3. Falsework settlement/deflection (if applicable).

The above calculation does not account for grinding and grooving. Before determining deck elevations, verify if the Contractor plans to texture the bridge deck by grinding and grooving. If grinding and grooving will be performed, an additional 1/4-inch of sacrificial concrete cover must be included to the bridge deck elevation.

Refer to Section 7-4.03, *Deck Grade Control Considerations*, for potential issues and items that may need to be accounted for when planning for grade control of bridge decks. These may affect the calculations of deck control points.

7-4.02B Deck Dowels

Control for the elevation of the deck and lost deck forms in box girder bridges is usually established using “deck dowels”, which are placed at the deck elevation control points. Deck dowels are typically short, straight pieces of rebar placed and cast into the girders at the deck elevation control point locations. They are installed vertically into the stems after the girders have been poured and while concrete is still plastic. Unlike permanent embeds, the dowels are permitted to be “wet-set”, making the timing of installation critical - if installed prematurely, the dowels may lean or sink; if too late they will be difficult or impossible to insert. Alternatively, they can be tied to the girder rebar beforehand and cast with the pour. The top ends should be set above the deck elevation. Before the stem and soffit pour, mark the locations of the deck elevation control points on the forms. The Contractor usually sets the deck dowels (if they are to be set) during the pour. When deck dowels are being installed, be cautious of interference with prestress ducts. This may be an issue when dowels are close to the bent cap, as that is where the high points of ducts are located.

After the stem and soffit pour, shoot and record the elevation of the top of the deck dowels during the following shift. In addition, prepare as-built sketches of the actual dowel locations which are used to fine tune the 4-scale layout of dowel locations, as required. On the days following the stem and soffit pour, contractors typically remove the walkways with the girder forms used during the stem and soffit pour. Girder forms are allowed to be removed 24 hours after the pour and are usually reused as lost deck forms. When the walkways are removed, safe access to deck dowels is lost. If this occurs, the Contractor must install adequate safety features to safely access the deck dowels before establishing deck~~s~~ grades in the field.

Instead of using straight bars, hook bars or "candy canes" may be used as deck dowels, as shown in Figure 7-10. This is to eliminate the need for impalement protection which is required if using straight bars. In this case, reference nails are installed next to the hook bars. Use the elevation of the reference nail rather than the dowel. Taking readings at the top of a hook bar can provide inconsistent elevations, as measurements will vary depending on the point of the curve the rod is placed on.

Figure 7-10. Deck Dowels (Hook Bars)

After determining the deck dowel (or reference nail) elevations, calculate the difference between these and their respective calculated bridge deck elevations. It’s good practice to summarize these calculations on a spreadsheet, showing all values used to determine the grade differences for ease of verification. Share the “cut” (or “fill”) calculations with the Contractor, along with a map (or simply a numbering system) indicating the locations of the corresponding control points/deck dowels within the bridge.

In the field, the Contractor will measure the "cut" dimension down from the top of dowel, then mark that dimension on the dowel. This mark signifies the deck elevation at that control point (see Figures 7-11 and 7-12). In some cases, they may use a hacksaw to make a saw cut on the deck dowel; this is preferred as tape used for marking may wear off, and the scored dowel is useful to secure stringline (explained in following pages).

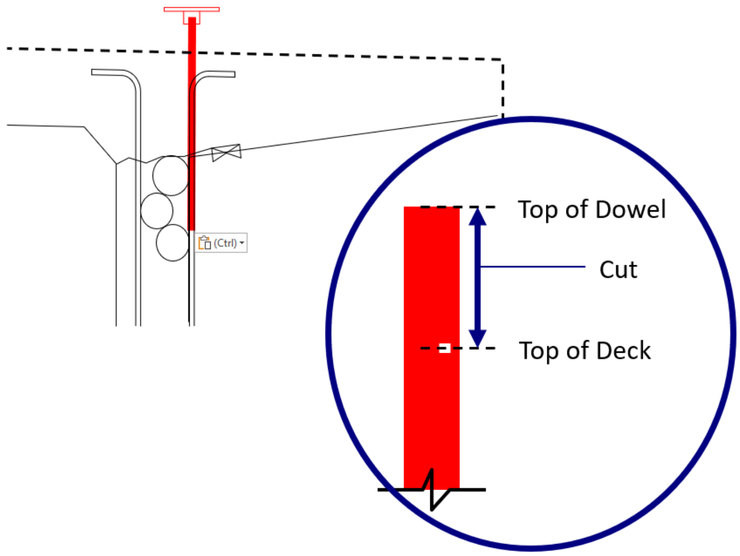

Figure 7-11. Deck Dowel Schematic

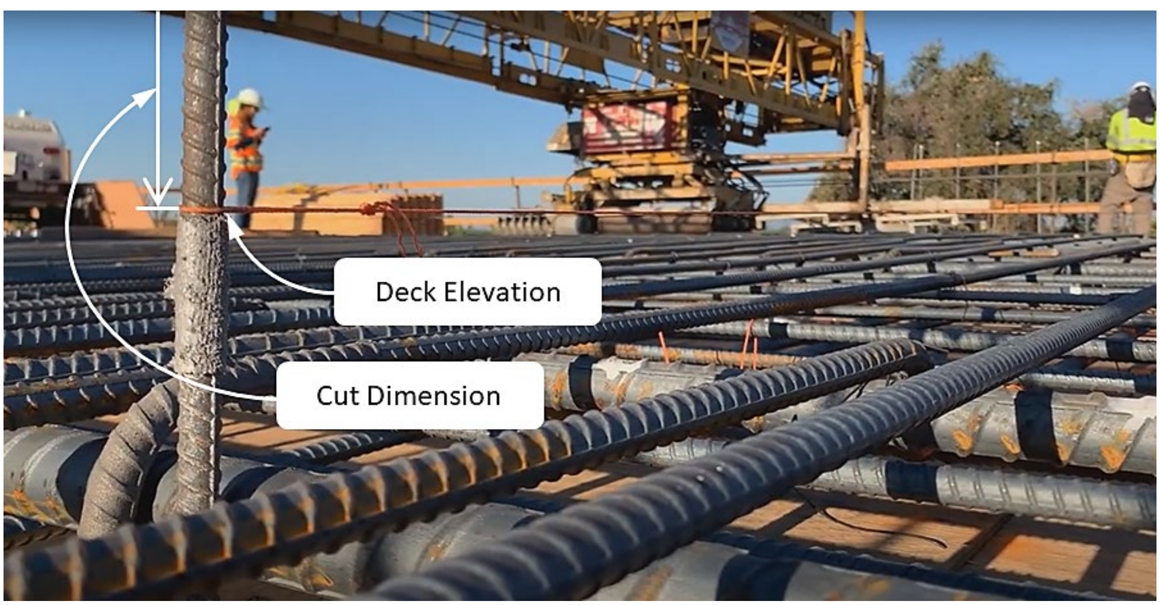

Figure 7-12. Cut Dimension Provided to Contractor on Deck Dowels

The Contractor will then stretch a stringline transversely across the deck to the deck dowel at the corresponding station. The solid lines in Figure 7-13 represent these stringlines, which indicate the target deck elevation to be constructed. Using the stringlines as reference, the Contractor can measure down the planned deck thickness to establish the correct elevation for setting the lost deck forms and supporting ledgers.

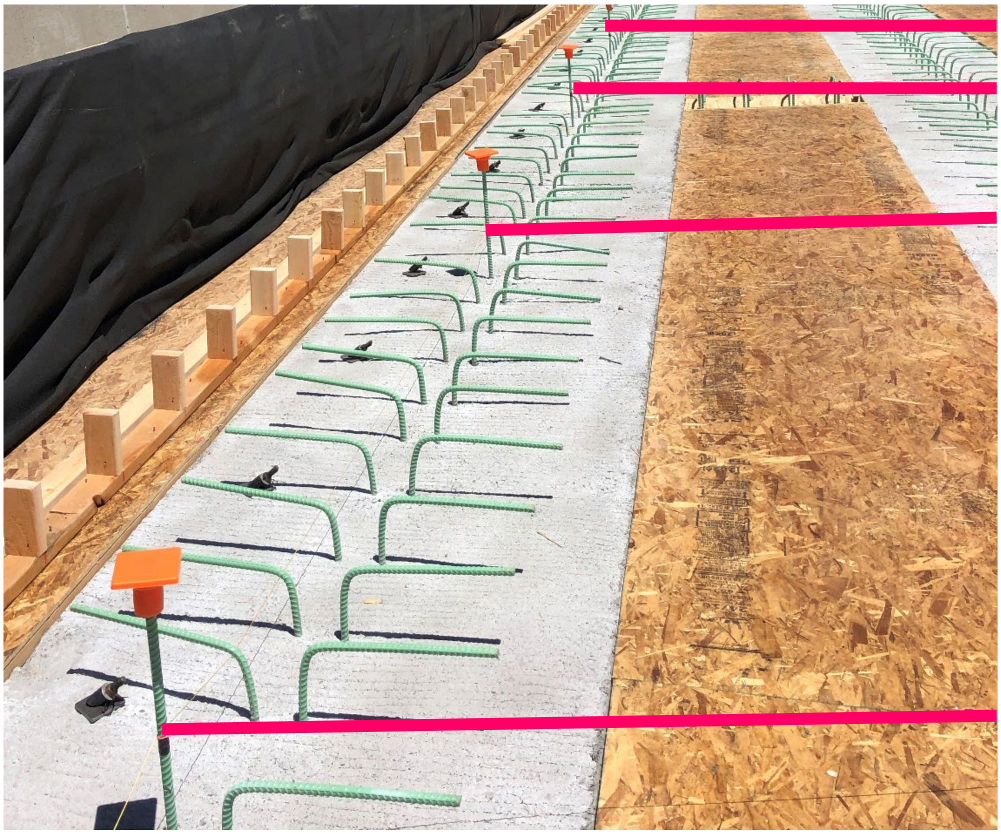

Figure 7-13. Deck Dowel Stringlines

If 1/4 inch is added to the deck elevations due to grinding and grooving, this additional deck thickness must be accommodated for when establishing the lost deck form elevations. Discuss with the Contractor how to account for added deck thickness.

SC staff should also pull string lines transverse and longitudinally to assess visually, or "eyeball", the deck elevations. Verify that deck elevations make sense, looking for potential grade busts or discontinuities. One way to accomplish this is by graphing the dowel elevations with distances from a referenced point using a spreadsheet program The carpenters may notice a grade bust as they snap out the ledgers that support the lost deck. Check how these grades correlate with previously placed concrete and rebar, such as proper stirrup height. Check also the height of previously poured girder stems and bent caps. The concrete may need to be built up to seal the forms or bushed down to place rebar at the proper location. Verify overall structure depth to top of deck.

7-4.02C Deck Overhang Grading

The deck overhang is formed, graded, and poured as part of the deck. Grade for the deck overhangs requires extra attention since these grades produce one of the more obvious lines of the structure.

Discuss the plan, methods, and manpower requirements for grading the overhang with the Contractor in advance. To get the required smooth lines that are the telltale hallmark of pride in workmanship, constantly review formwork construction with the Contractor throughout the project. Emphasize form continuity and the importance of rechecking previously graded points with the Contractor. Sometimes, previously graded points change in elevation as the overhang is graded.

As mentioned previously, the overhang should have been rough graded earlier to prevent potential incorrect alignment when edge of deck forms were set.

First, determine overhang elevation control point locations along the edge of deck, where grade adjustments can be performed on the forms. Typically, these will be directly over the overhang supports or posts. Spacing must conform with *Contract Specifications*, Section 51-1.03F(5)(a). Shoot and record the elevations of the overhang forms at the overhang elevation control points. If at this stage, edge of deck forms have been installed with chamfer strips attached to set the top of the concrete pour line, it is acceptable to shoot and record directly the elevations of the chamfers at the control points. Verify that the height of the chamfers with respect to the overhang forms matches the planned edge of deck thickness.

Next, field-measure the locations of the overhang elevation control points and plot these on the 4-scale plot. From the plot, determine the deck elevations at the overhang elevation control points. Using this information, calculate the theoretical elevations at the overhang elevation control points on the forms itself by adding the following values:

1. Contour elevation
2. Long-term bridge camber
3. Overhang thickness (subtract)
4. Adjustments to account for falsework stringer deflection (if applicable).

If using elevations shot on the overhang forms, subtract the edge of deck thickness; however, do not subtract this thickness if using elevations shot directly on the chamfer strips. Lastly, calculate the difference between the elevations shot and their respective theoretical elevations. Provide these “cut” or “fill” calculations to the Contractor, as these values represent the required grade adjustment.

Before the Contractor grades, or adjusts, the overhangs, enough load should be on the forms to tighten up the joints. Usually this is accomplished when a major portion of the deck reinforcement is in place.

It is common practice for the Contractor to rough grade the overhang approximately 0.25 to 0.50 inches low because it is easier and quicker to jack or wedge the overhang up rather than to try to lower it (see Figure 7-14). Another common practice for overhang posts is to shoot grade and set elevation at every other post and then shim up the intermediate posts, thus reducing the amount of effort without compromising quality. For overhang forms with multiple supports, both the interior and exterior supports should be graded simultaneously before the final grading work to prevent overhang support geometry from causing a grade change at the edge of deck. After grading, the Contractor should feather wedge or shim the joists tightly. As a final check, eyeball the edge of deck profile with the Contractor. Confirm that the overhang forms and chamfer strips create a smooth and consistent appearance.

Figure 7-14. Wedge System for the Overhang

If the Contractor uses jacks for grading, verify that they are installed and used per the manufacturer's recommendations. For example, monitor that jacks do not extend too far and vertical legs and screw adjustments are plumb. Check lumber for defects and watch for tipped joists.

7-4.03 Deck Grade Control Considerations

When widening or constructing a new bridge deck, SC staff and the Contractor must work together to ensure the new deck is graded properly. The potential for grade and elevation issues can be minimized, particularly at the project start, with careful attention to detail, an understanding of potential hurdles and problems, and foresight. It is more efficient and effective to do the job correctly and thoroughly the first time than to attempt reworking improper grading at the last minute. Below are several grade control considerations for construction of various types of bridge decks.

7-4.03A Bridge Widenings

Contours for bridge widening are typically not provided by the Bridge Design (BD) Project Engineer. Instead, the contours of the new deck are derived from the contours of the existing bridge deck that is being widened. SC staff usually develop the new deck contours by first generating the as-built contours of the existing deck and then extending those contours onto the layout of the new deck; District Surveyors may be utilized to assist with this process. This process can be completed manually or with the assistance of CAD software. Figure 7-15 shows a concrete deck pour for a bridge widening which required its deck contours be developed based on the existing bridge decks.

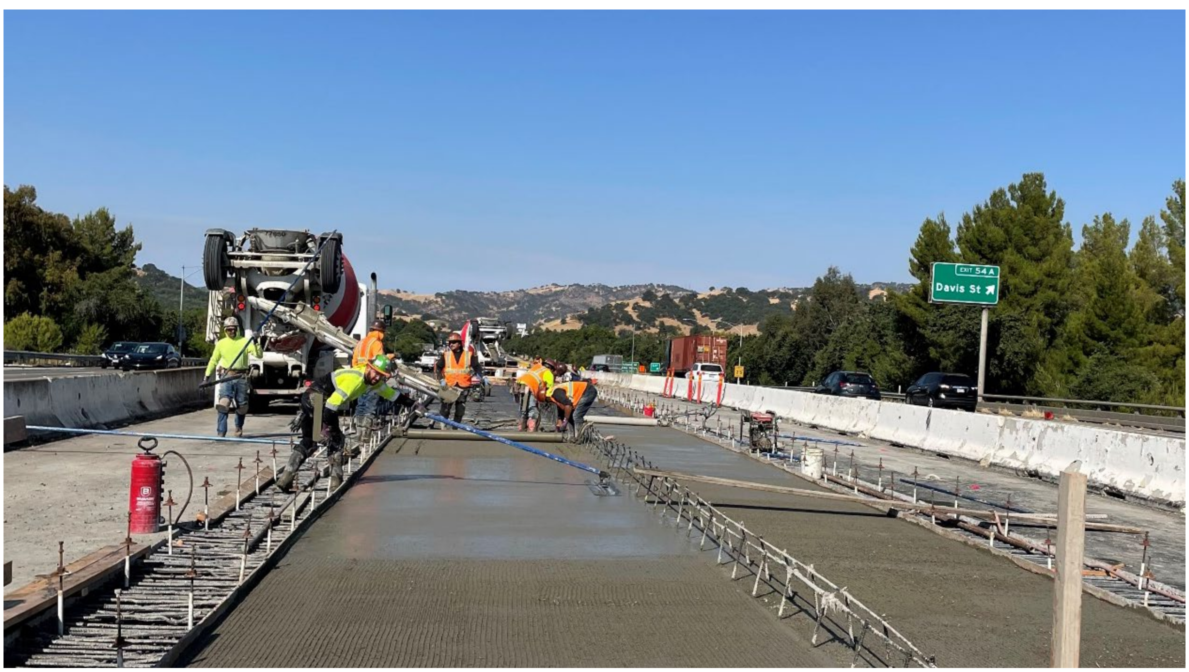

Figure 7-15. Bridge Deck Widening

Some features of existing decks that may cause problems include:

1. Too much camber.
2. Too little camber.
3. Bumps not corrected on the original contract.
4. Rough surfaces and other defects under removed overlays, curbs, and rails.

These problems can be corrected with grinding or overlays.

Sometimes medians are widened so that the new deck must match two existing bridge decks and a theoretical centerline profile. This type of widening may result in the existing bridge deck profiles conflicting with each other and the theoretical centerline profile. If this occurs, adjust the profiles, vary the deck slopes, or explore alternative solutions. Keep in mind the potential impacts to surface flow and any proposed drainage inlets or appurtenances.

Closure pours between new left and right structures pose similar challenges. If possible, determine the existing bridge deck profile elevations and cross slope by requesting the Contractor to pothole overlays on existing bridges that need widening.

Identify grade problems and potential solutions early. When edge profiles for the existing decks and roadways are included in the project plans, verify they match the actual deck profiles before construction starts to determine if remedial work is necessary. This can be performed by developing the as-built profiles of the existing deck and comparing them with those in the project plans. For structures that cross over ramps, roads, or tracks, verify that required permanent clearances will not be impaired by using the field-acquired grades and projecting the planned widening girder bottoms or soffit elevations from the existing structure.

7-4.03B New Construction

On long ramp structures, viaducts, and structures requiring multiple pours, bumps may develop at transverse bulkheads or construction joints, expansion joints, or hinges. Proper profiling and grade control of the adjacent work safeguards against grade or slope discontinuities at the edge of deck grades.

Extra care and caution are required when a subsequent deck pour must match a previous deck pour at a hinge or a transverse construction joint. Proper attention at the end of the previous pour is essential to obtain a satisfactory joint. It is much easier and more effective to match a correctly poured joint than it is to correct irregularities later on.

After the initial deck pour, create a cross-section and profile of the deck. Establish a grid of points the day after the pour at even stations and offsets. Shoot and monitor elevations of the initial deck pour regularly, until it is time to establish elevations for the next deck pour.

While monitoring the elevations, check for the possibility of long-term falsework settlement and movement of post-tensioned hinges, including hinge curl; this is especially critical on the short end of hinges, which creep upward due to prestressing forces. Refer to Bridge Design Memo, 5.23, *Hinge Curl,* for more information regarding this phenomena. Adjust soffit grades, lost deck, and screed grades if necessary. Extend and compare profiles of the initial deck to the subsequent deck profiles with theoretical values. Then, adjust the grades for the subsequent deck pour accordingly. If major adjustments appear to be needed, consult with the BD Project Engineer.

7-4.03C Dead Load Deflection, Camber, and Settlement

Deck camber for PC PS concrete girder and slab bridges is dependent on the elapsed time between stressing the girders and placing the deck. Because concrete for a PC PS member continues to gain strength and a significant portion of the dead load is not applied to the girders until the deck is placed, the girders tend to creep, or deflect, upwards (see Figure 7-16). The Contractor furnishes camber calculations for PC PS girders and shows them on the shop drawing submittal. When reviewing the shop drawings, pay attention to the time between casting and storage of the girders and the placement of the deck, especially for stage construction projects and widenings. This topic is discussed further in Chapter 8, *Precast Concrete*.

Figure 7-16. PC PS Girder Camber

Deck camber for steel girder bridges includes the initial deflection of the girder(s) from the dead load of the deck but does not include the deflection caused by the weight of the girder(s). In the case of composite design, add a residual amount to compensate for the additional deflection due to drying shrinkage of the slab; contact Bridge Design for guidance as required.

On bridge widenings, the *Contract Specifications* frequently requires falsework supports to remain in place for a longer period, compared to new construction. The specifications may also require that a minimum time elapse between closure pour and falsework release to reduce relative movement between two structures across a closure pour between widened and existing decks. Depending on the amount of camber and the time of the closure pour, the total anticipated deflection for the widening section next to the existing bridge may never be realized. Therefore, it may be necessary to reduce the amount of camber for this section to reduce possible grade differentials that could develop between the widened and existing decks.

As with falsework members, the dead load deflection of steel girder bridges must be checked. Before steel girder fabrication, check the effect of built-in camber using the 4-scale layouts. Use fills from the girder flanges to grade deck forms and screed rails for steel girder bridges.

There are three important factors to remember in connection with steel girder profiles:

1. Safety: Do not perform any work without adequate personal protective equipment and safety measures, such as fall protection equipment and safety rail running the length of the girder. See Caltrans *Health and Safety Manual*[1], Chapter 12, *Personal Protective Equipment,* and Chapter 25, *Fall Protection.*
2. Grade points: Accurately lay out grade points and reference them to the centerlines of bearing.
3. Elevation check timing: Only run level circuits early in the morning when temperature variation is minimal and while the girder temperature is uniform and constant. Do not return later in the day and attempt to check elevations. These elevations may not even be the same the next morning. Record the ambient temperature of every survey.

For most bridge types, settlement can occur in the falsework and the forming system. Bridge deck settlement normally results from form take-up, assuming that falsework settlement has stabilized.

Exceptions include:

1. Slab bridges where settlement is compensated for by screed adjustment during concrete placement activities.
2. Post-tensioned bridges where falsework settlement occurs because of prestressing forces applied after deck pour.
3. Deck-forming systems like overhangs, designated as falsework.

[1] Caltrans Internal use only

The SC *Falsework Manual* addresses the issue of falsework settlement. Some degree of settlement is normal due to the take-up in forms; however, the quality of workmanship must ensure that the falsework that will support the anticipated loads without excessive settlement or compression beyond what is specified in the falsework shop drawings.

Tie together all grades used for deck construction and always check back and tie in to previously shot grades for continuity. Check deck dowel grades when shooting overhang grades to check for long-term falsework settlement. Coordinate stationing and level data between adjacent pours to provide a matching deck surface. Location and accessibility to benchmarks require foresight to prevent the loss of key elevation points.

7-4.04 Bridge Deck and Overhang Form Workmanship

The quality, workmanship, and inspection of bridge deck and overhang formwork are no different than for other bridge elements and structures. The guidance outlined in Chapter 3, *Forms*, applies to the construction of bridge deck formwork. Any formwork issues should be resolved before reinforcement is placed, as any corrective action would be difficult to perform afterwards. The following provides additional considerations for bridge deck formwork.

Verify that lost deck and overhang formwork is being constructed per the authorized falsework shop drawings. Items to be aware of include correct material types and sizes, connections, layout, spans, spacing, etc. Any changes to the formwork construction may require the Contractor to submit revised shop drawings per *Contract Specifications*, Section 5-1.23B(2), *Control of Work – Submittals – Action Submittals – Shop Drawings*.

Check that forms are being installed at the correct elevations. For lost deck forms, reset stringlines transversely between the deck dowels. Then measure from the stringlines to the top of the plywood as shown in Figure 7-17. This measurement must closely correspond to the planned deck thickness.

Figure 7-17. Lost Deck Measurements

Joints in overhang forms must be solid to prevent differential deflections due to the weight of the finishing machine. Look for potential stability problems such as a tipping overhang caused by loads being concentrated along the outside section of the overhang.

As with all forms, deck forms must be mortar tight. Because the concrete placed on lost deck forms is not visible, the importance of mortar tightness is sometimes overlooked. However, forms that are not mortar tight can cause hidden rock pockets and affect the structural viability of the deck.

When the concrete surface will be exposed after construction, mortar tightness and surface condition of the forms are especially important. Plywood overhang forms must conform to the same conditions as soffit plywood.

When overhang forms are constructed simultaneously with the exterior girder stem forms, the overhang forms must be kept clean and protected from hazards that may negatively affect the deck overhang's surface finish. One method to protect overhang forms is to install protective covers over the form using plastic sheeting, lost deck plywood, or building paper. If the overhang forms are built after the girder stem pour, check the grade at the exterior girder before the deck reinforcing steel is placed. Always check the lumber for defects as the overhang forms are being constructed. On sharp radius curves, gaps will occur between plywood and stem, and at joints. Some patterns must be developed to mitigate this. Verify that standard plan drip grooves are installed if the plans require them.

Before lost deck forms are completed, check that material other than lost deck formwork has been removed from inside the bridge cells. *Contract Specifications*, Section 51-1.03C(2)(b), *Removing Forms,* requires these areas to be clear of loose material.

7-5 Bridge Deck Reinforcement

The guidance and practices detailed in Chapter 4, *Reinforcement*, are applicable to bar reinforcement of bridge decks. The following sections provide additional considerations specifically relevant to bridge deck reinforcement.

7-5.01 Standard Plans

Standard construction details for bar reinforcement are located in the *Standard Plans*. The *Index to Plans* sheet of the structure portion of the project plans usually lists the referenced standard plan sheets.

Following are examples of commonly used details for bridge deck construction from the *Standard Plans*:

1. Standard Plan B0-5, *Bridge Details,* lists transverse and longitudinal reinforcing spacing requirements, location of deck construction joints, and deck reinforcing placement notes.
2. Standard Plan B7-11, *Utility Details,* if there are access openings in the deck, check B7-11 for reinforcing details. Review the plans to ensure that access openings are not in wheel lines. If there is a conflict, discuss it with the Structure Designer.
3. Standard Plan B7-5 through B7-8 for placement of deck drains.
4. Standard Plan B11-58 through B11-87 for concrete barrier details.

7-5.02 Detailing and Fabrication

SC staff provide 4-scales to the Contractor. In turn, the Contractor should make them available to their reinforcing steel fabricator to reduce the probability of detailing errors. Special details for deck reinforcing and change orders affecting reinforcement should be brought to the Contractor's attention.

Errors in detailing or fabrication are more likely to occur on bridges with the following characteristics:

1. Varying girder spacing
2. Varying deck thickness
3. Large skew
4. Varying skew
5. Small horizontal curve radii
6. High and/or variable cross slope.

The potential effects of some of the above characteristics are discussed further in Chapter 2, *Preconstruction Planning*. Fabrication is seldom a problem if the standard industry practices for fabrication dimensions are followed.

7-5.03 Bar Reinforcement Installation

Periodic and timely inspections are strongly recommended during bar reinforcement placement for early detection and correction of errors. Proactive and timely inspection can reduce construction time and minimize re-work costs.

Check the heights of the girder stirrup tails, particularly in the exterior girders. Stirrups that are too low may require additional blocking for the top mat of rebar to be set at the correct elevation. Stirrups that are too high may need to be bent or otherwise modified, to not encroach into the clear cover. Also, it is common practice for project plans to not include details of required reinforcement that is shown in the *Standard Plans*, especially modified barrier rail details for barrier mounted utilities.

On bridges with the characteristics listed in preceding Section 7-5.02*, Detailing and Fabrication,* watch for incorrect reinforcing in the corners, incorrect bar termination location, omission of bars at the overhangs and bent caps, etc. In addition, consider the effects of “stack height”, or the total vertical height of multiple layers of bar reinforcement placed on top of each other. The calculated stack height can potentially conflict with the specified clearances if not properly accounted for during design and detailing. Conflicts should be discussed with the BD Project Engineer.

7-5.03A Before Bar Reinforcement Placement

Construction joints, including the joint between girder stems and deck, must be adequately prepared to provide a strong bond between both bridge elements. The Contractor is responsible for abrasive blasting the surface of the construction joint to remove curing compound, laitance, and poorly consolidated concrete. This preparation should be performed before the start of bar reinforcement placement.

7-5.03B Transport and Loading

Contractors typically use cranes to transport reinforcement onto the deck forms for placement by the ironworkers. The crane can deposit very large bundles of rebar on the deck. It’s possible for the bundles of rebar to overload the falsework. Discuss with the Contractor how and where the reinforcement will be stored and loaded onto the deck forms and compare this with the loading assumed in the authorized falsework shop drawings.

7-5.03C Clearances

Correctly placed deck reinforcement that provides the planned clearance or cover for the bars is vital. Insufficient cover can fail to protect reinforcement from water and chloride intrusion, resulting in rusting. Rusting rebar causes spalling and loss of structural section, dramatically shortening the life of the deck. This is especially true in a marine environment or where de-icing chemicals are used. Project plans may require a cover larger than 2 inches for bridges in these environments. A significant amount of bridge maintenance funding is spent on deck rehabilitation projects. Deck reinforcement and clearances must match project plans to reduce future deck rehabilitation costs.

Always inspect the clearance to the top of the deck, the minimum clearance at the boundaries, and the bar reinforcement ends to make sure they match the typical section in the project plans. Clearance from the top of deck can be verified by checking the distance between deck dowel stringlines and topmost reinforcement. Be attentive to clearances in areas where there is more reinforcement than other locations along the deck, such as bents and hinges. The same is true at locations where grinding is usually required, such as hinges and bridge deck construction joints.

Check to see if there is adequate space for deck drainage and other bridge deck embeds to be installed in the overhang. It may be more advantageous if these embeds are installed before bar reinforcement placement.

7-5.03D Blocking and Tying

All deck reinforcement must be blocked up off the deck forms so that concrete can encapsulate the lower mat. *Contract Specifications*, Section 52-1.03D, *Reinforcement – General – Construction – Placing,* does not allow wooden, plastic, or aluminum supports to be used. Ferrous metal chairs, if used, must have at least a 1-inch cover. The plastic coatings on the chair feet are not considered an effective cover. The *Contract Specifications* also do not permit placing bar reinforcement into wet concrete during the pour. Precast mortar blocks, or dobies, are frequently used and acceptable to attain the required concrete cover on the bottom rebar and for ferrous chairs.

Between the girders, “ducked" or buried bars are usually shown on the project plans to support the bottom mat. Typically, they are #4 bars spaced at about two feet on center. Details for how buried bars would appear on project plans are shown in Figure 7-18.

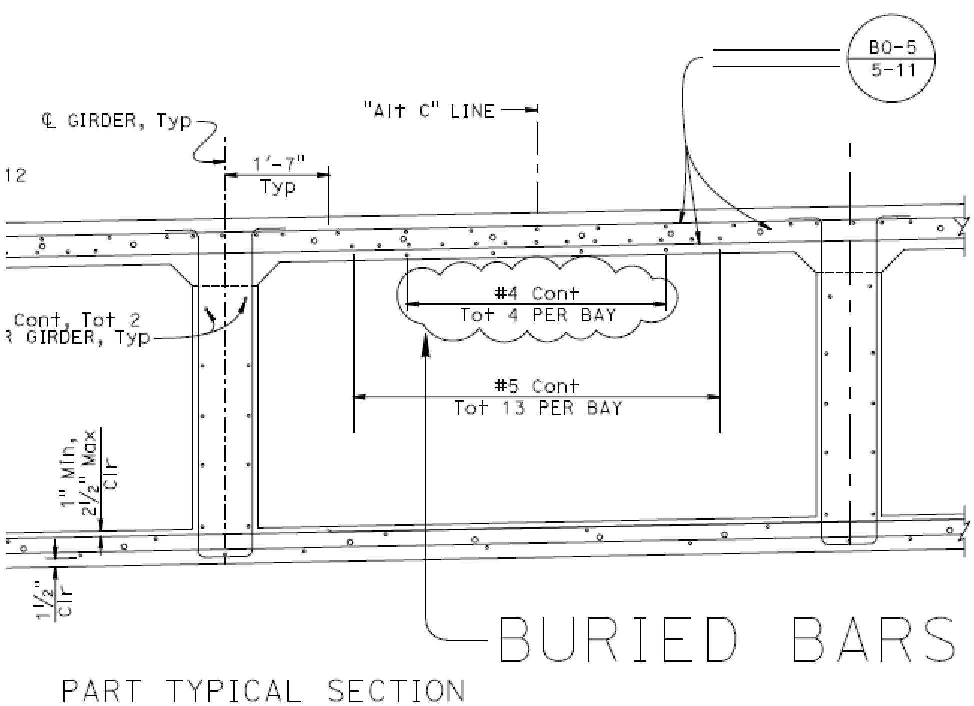

Figure 7-18. Buried Bars Details

Contractors typically use dobies to support the top mat. At or near the girders, some contractors will attempt to support the top deck mat on the stirrup tails. This can be an effective support method, provided that the tails are correctly positioned to perform this task and the bars are securely tied to the tails to prevent movement before or during the pour. The Contractor had previously been given the option to use truss bars, if shown on the project plans, as the transverse bars in the top mat; however, projects dated after 2024 no longer provide the truss bar option.

Mats of bar reinforcement must also be tied firmly and securely in position to prevent movement during deck concrete placement. This is accomplished by wiring at intersections and splices. American Concrete Institute (ACI) recommends that bars be tied at every other intersection, and this may be adequate in most cases. More frequent tying may be necessary at corners, over bent caps, and other special locations.

7-5.03E Splices

Lap splicing is the most common method of splicing small diameter deck bars. Ensure that lap splices are of required length and staggered as required in the *Contract Specifications*.

Service splices or ultimate butt splices in the deck may be required per the contract documents. Record the locations of service splices and ultimate butt splices on the as-built plans per Bridge Construction Memo (BCM) C-6, Attachment 3, *Guidance for Completing As-Built Project Plans*.

7-6 Pre-Pour Construction Activities

The period leading to a bridge deck concrete pour can be quite hectic. The prime contractor and their subcontractors often focus on multiple aspects of the bridge deck until the start of the pour, resulting in several contractor personnel working simultaneously in the same area. Effective preconstruction planning and timely inspections can head off many potential issues. The following subsections outlines some of the activities that typically occur the immediate weeks or even days before the deck pour, which SC staff must be particularly attentive to.

7-6.01 Screed Rails

Since screed rails are normally placed on the overhang forms, one method for grading is to shoot the screed rails using the overhang grades and adjust the Lenker rod to compensate for the elevation difference between the overhang and the screed rail. Alternatively, the Contractor may use a template, or “story pole,” set on the graded overhang to grade the screed rails. As a last resort, they can grade both the overhang and the screed rails from the deck grades on the exterior girder.

Once they are set to the proper elevation, verify smoothness of the profile by sighting ("eyeballing") the screed rails. Reverify reinforcement clearances and deck thickness by measuring from a stringline stretched between the screed rails to the topmost reinforcement and forms, respectively, similar to what should have been done earlier using the lost deck grade dowels.

Spot-check screed rails for adequate support. Screed rails that are not placed on the overhang but rather within the deck should be installed over bridge girder stems, if possible, for best support.

Bridge deck finishing machines ride along screed pipes during the concrete pour. These pipes are typically 2-inch diameter heavy wall pipe with screed chair supports spaced to not exceed the manufacturer's recommendation, typically 24 to 30 inches. Check that the screed pipes are in good condition. Bring to the Contractor's attention any irregularities found on the screed pipes, as they may need to be replaced.

Screed pipes should run the full length of the pour and extend beyond both ends of the pour, enough for the finishing equipment to start and clear the pour area (see Figure 7-19). This is particularly important if any of the ends are on a skew. Screed pipes must be graded beyond the limits of the pour for proper grade at the bulkheads and paving notches. Screed pipe splice sleeves should be placed to prevent cantilever action of the screed pipe.

Figure 7-19. Screed Rails Extended Beyond Pour Limits

Vibrations can cause the adjustment nuts of the screed pipe saddle and overhangs to turn unintentionally. To prevent this, one practice is to wire or secure them. Check all screed support elements during concrete placement.

Non-uniform screed rail displacement or settlement can be caused by:

1. Lack of washers between adjusting nut and edge of deck panel.
2. Spaces between top plate and studs of overhang panel.
3. Spaces between overhang plywood and EOD forms.

Make field notes and have a level available during every deck pour in case of grade problems.

7-6.02 Deck Construction Joints and Bulkheads

Contractors often use construction joints utilizing bulkheads to construct CIP concrete elements in stages. As mentioned in Chapter 5, *Concrete*, planned construction joints are either shown in the project plans, or proposed by the Contractor and authorized by the Department. Treat any construction joint, transverse or longitudinal, as a potential bump or problem area. Check all work in the vicinity of a transverse bulkhead carefully, particularly grade control.

Transverse construction joints for bridge decks should be placed around 0.20 to 0.25 span length from the bent centerline, as noted in *Standard Plans*, B0-5 and B7-1. These locations usually correspond with the inflection points of the bridge span, where bending stress is minimal. Transverse deck construction joints may also be located at the deck compression areas if authorized. The bulkhead for the construction joint must be fabricated to form a keyway or integrate expanded metal mesh, as detailed in the Standard Plan B0-5.

Reprofile the deck adjacent to the bulkhead before the subsequent deck pour to verify deck elevations match.

Contract Specifications, Section 51-1.03D(4), *Concrete Structures – General – Construction – Placing Concrete – Construction Joints,* and Standard Plan B0-5 require longitudinal construction joints be placed at edge of lane lines for bridge decks if not shown in the project plans. Verify that longitudinal bulkheads are installed so that joints satisfy this requirement. In the past, there was a tendency to incorrectly place longitudinal bulkheads within a foot of the lane line.

For positive support, it is good practice for longitudinal bulkheads to be installed close to the girder stems whenever possible. For portions of bulkheads located above a bridge cell and installed on the lost deck, deflection and settlement can be minimized by adding additional vertical supports, or “legging up”, against the soffit.

Discuss reinforcing steel splice details related to joint location with the Contractor before reinforcing steel fabrication, and again during deck concrete placement planning. Grading transverse bulkheads is similar to grading paving notches, described below.

Ensure that bulkheads and other deck forms are constructed, cleaned and stripped in accordance with *Contract Specifications*, Section 51-1.03C(2), *Concrete Structures – General – Construction – Preparation – Forms*. Do not allow early stripping of forms which can result in damage to the concrete. Prohibit simultaneous pouring on both sides of a joint.

7-6.03 Paving Notches and Expansion Joints

Forms for paving notches and expansion joints should be graded approximately 0.25 to 0.5 inches low to clear finishing equipment. When the paving notch (for a diaphragm type abutment) is not formed before the girder stem pour, concrete for the girder stem or abutment diaphragm must be set low enough to receive the paving notch forms. Make sure there is an adequate method for holding the paving notch to proper line and grade.

After final floating, for dressing and edging the joint, the Contractor may attach a filler strip or edger board to the form or saw cut the edge later. After the finishing machine passes, the Contractor should check the section of deck leading up to the joint at several locations with a straightedge held longitudinally to the bridge, as shown in Figure 7-20.

Figure 7-20. Checking Freshly Placed Deck Concrete Near the Expansion Joint Blockout

Proper width, straight, and plumb joints are important when saw-cutting for Type B joint seals. Check reinforcing steel clearances, sealed hinge joints, and paving notches for possible interference with the joint seal saw cuts. Straight material, such as a nailing strip, should be used after finishing operations to establish the grade. The strip should be nailed to the paving notch and used as a guide for edging only. Use of a 0.25-inch edger without depressing the concrete, or similar methods, may be acceptable.

At expansion joints, it may be prudent to slightly increase the deck thickness, thereby slightly raising the deck elevation – while maintaining the bar reinforcement at or just below its planned elevation. This approach accommodates possible future grinding to address potential profile discontinuities between both sides of the expansion joint.

7-6.04 Bridge Deck Finishing Machines

Contractors almost always employ bridge deck finishing machines for striking off and finishing bridge decks, and to achieve the planned deck elevation. Finishing machines from Terex® Bid-Well are used frequently for bridge decks in California. Other brands of finishing machines used include the Allen Engineering Corp and GOMACO Corporation. For guidance on setup, adjustments, grading, and maintenance of specific brands of bridge deck finishing machines, refer to the manufacturer's instructions or manuals.

The basic bridge deck finishing machine features a carriage fitted with concrete finishing equipment. The carriage is suspended from rails attached to an open welded steel truss frame, or the machine truss. Depending on the width of the concrete deck to be poured, the machine truss can be made of one or more truss sections. The machine truss is positioned parallel to the bridge skew. The carriage moves left and right as the machine truss travels forward, maintaining alignment with the bridge skew, if applicable. A typical bridge deck finishing machine is shown in Figure 7-21.

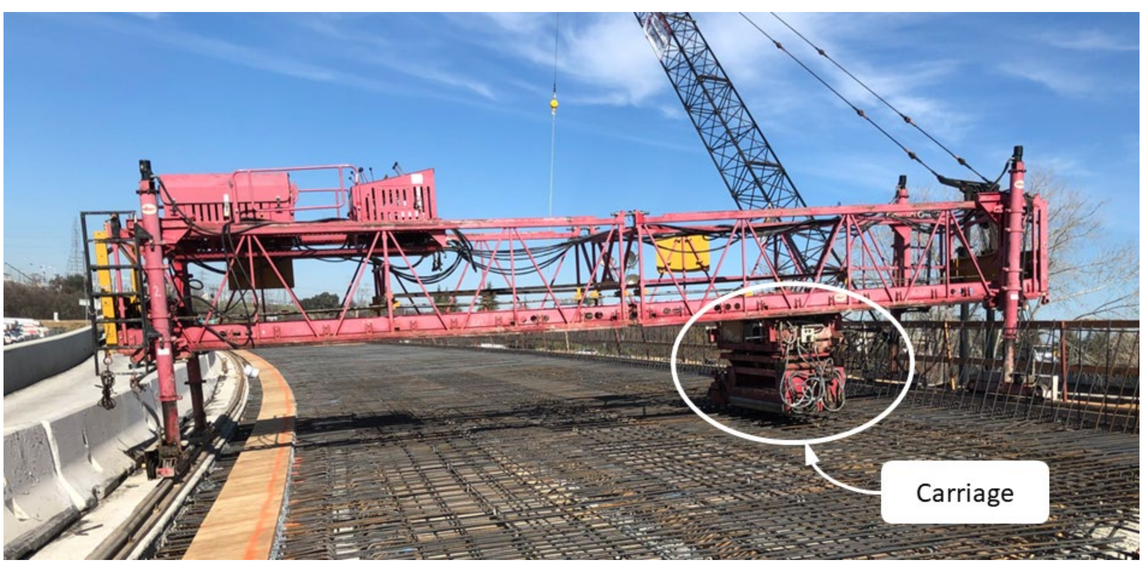

Figure 7-21. Bridge Deck Finishing Machine

The machine truss is supported by adjustable legs equipped with sets of wheels, commonly referred to as “bogie wheels”, which ride on screed pipe rails. Powered bogie wheels move the bridge deck finishing machine longitudinally on the screed rails.

The finishing equipment mounted to the carriage includes augers (typically placed 1/8 to 1/4 inch above finished grade), roller tamper drums, paving rollers, and drag pans. A burlap drag is usually attached at the rear of the carriage. These components are arranged sequentially to spread, finish, and texture the concrete surface with each pass. Figure 7-22 shows the finishing equipment components attached to the carriage. The truss assembly can be adjusted to achieve the designed bridge grade, and cross section. Note that the machine truss in the figure has been adjusted to incorporate a planned crown on the bridge deck.

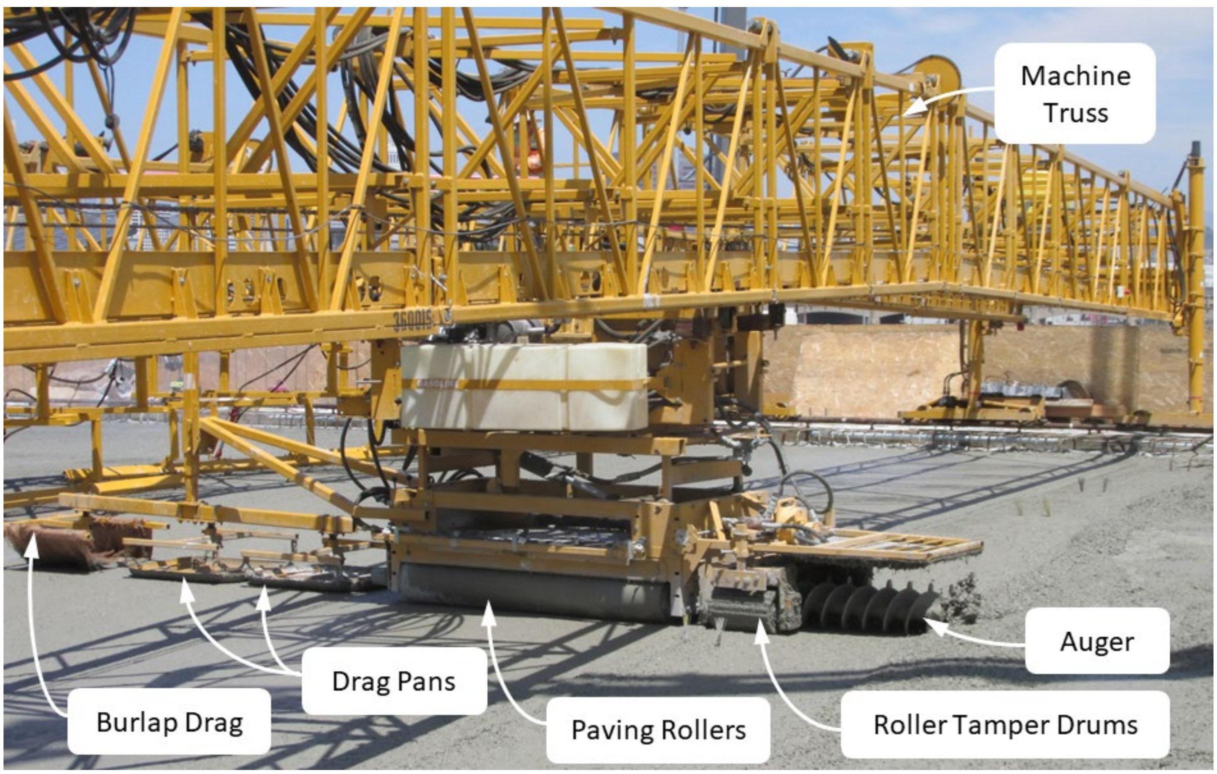

Figure 7-22. Components of a Bridge Deck Finishing Machine

During the deck pour, the augers strike off the concrete to a rough grade and move excess concrete forward. Next, the roller tamper drums compact and consolidate the concrete. The paving rollers follow, further consolidating the concrete and screeding the concrete to grade. After the paving rollers pass, a drag pan or a series of drag pans fill in small voids remaining and seals the surface of the concrete. The burlap drag produces an initial texture before the final longitudinal texture is applied.

The Contractor must be careful when adjusting the bridge deck finishing machine. Depending on the equipment, adjustments may take three to eight hours to complete. Figure 7-23 shows the Contractor adjusting the height of one of the machine truss legs. Proper machine maintenance and care is crucial. Many manufacturers recommend all moving parts be lubricated. If the machine appears to suffer from poor maintenance, be extra cautious. Suggest to the Contractor to have backup material on hand, such as chain repair kits, belts, extra bearings, sprockets, etc. The Contractor usually does not have an alternative deck finishing method readily available in case the finishing machine breaks down.

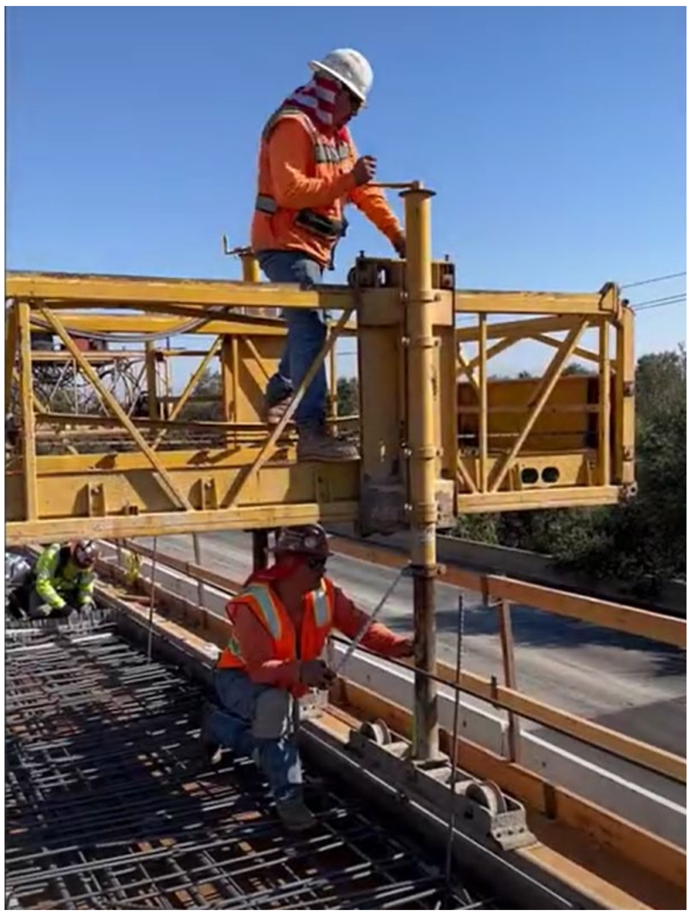

Figure 7-23. Inspect Adjustment of the Finishing Machine

Subtle adjustments of the machine during a pour for a 0.02-foot change in grade often do more harm than good. Although much has been said and written about how a finishing machine can be programmed for various subtle changes in grade, it is more prudent to leave the machine at one setting for the entire deck pour.

Contractors typically, and should, make fine adjustments and perform a final dry run of the finishing machine the day before the scheduled concrete pour. All equipment, material, and personnel that will be on the finishing machine during the pour should also be on the machine during the dry run. The gas and hydraulic tanks should be filled to account for the additional load, and to properly set the finishing machine truss camber. SC staff must actively inspect and be heavily involved during these critical operations. The following is the typical method followed by contractors for setting up and adjusting the bridge deck finishing machine (double or single roller):

1. Stringline the length of the assembled truss and carriage rail, adjusting for crown or no crown conditions (make sure carriage is at center of truss and string line is not sagging).
2. Move carriage to left or right side of deck adjacent to legs.
3. Place stringline, which represents finished surface, across deck and parallel to trusses. Distance from truss rail to string on both sides of roller carriage should be equal.
4. Move machine over string line until ends of both rollers are over the string. Check finishing machine height with lowest end of paving rollers over string line (see Figure 7-24).

Figure 7-24. Check Finishing Machine Height

5. Check distance from roller surface to string. It should be the same for both rollers.

6. Lower or raise rollers to stringline via leg adjustment. Move both legs-fore and aft-an equal amount.
7. After final adjustment of the legs, mark them with marker or tape to ensure that they do not move prior to or during concrete placement.
8. Repeat steps 4 to 7 by moving finishing machine transversely and forward until back end of rollers are checked. Rollers should also be checked at deck drain inlets and other embedded objects that are to be flush with the bridge deck surface.

In addition to using stringlines as mentioned above, a 4 to 6-foot-long 2-by-4-inch nominal size lumber placed flat on the upper reinforcement can also be used in conjunction with stringlines to verify cover. The advantage of using 2-by-4-inch nominal lumber is that the lumber can be easily moved as the finishing machine progresses forward during the dry run. Also, with the actual thickness of 1.5 inches, a quick visual reference is achieved to the bottom of the rollers. Spot-check clearances at locations that are typically questionable, such as girder stirrups, with the lumber, as shown in Figure 7-25. Another critical location to check is the crown of any vertical curves, especially on skewed or tight-radius bridges. The combination of skew and crown can result in the finishing equipment “scalping” the deck as the equipment effectively straddles the uppermost point of the crown. Afterwards, use the stringline method to double check possible reduced clearances that were found with the lumber.

Figure 7-25. Clearance Checking with Lumber

If reduced bar reinforcement clearances are found during the dry run, the Contractor must adjust or bend the bars down to meet required clearance. It is good practice to carry flagging ribbon and/or paint (typically blue for ironworkers) to mark out areas requiring adjustment, and keel/crayon to note the amount of adjustment required. This facilitates an efficient correction process and ensures noted issues are not missed. Final grades may be modified as a last resort if authorized by SC staff.

Additionally, take a measurement from the strike-off or rollers of the finishing machine during the adjustment of the machine, to verify desired clearance is achieved.

Pay attention to the auger adjustment and roller skew. At the beginning of the concrete pour, observe the auger adjustment. Often, it is not set low enough, which causes the rollers to load up and results in a ridge behind the machine. The skew of the rollers is critical during the pour. If a ridge is left behind the roller, it may be due to a change in the skew of the centerline of the rollers. This may be corrected by moving one side of the machine forward or back. The SC website features a link to a video titled *Bidwell Operation and Set-up*[1], which offers a basic introduction for SC staff on the standard setup process for a bridge deck finishing machine.

The use of any specific proprietary finishing equipment is not required. Other methods, include hand screeding with a straight edge or the use of a roller screed as depicted in Figure 7-26 may be used if feasible. These are very labor-intensive methods and subject to the skill of the finishers. These activities must be closely controlled and inspected if used.

Figure 7-26. Roller Screed for Deck Finishing

[1] Caltrans internal use only

7-7 Bridge Deck Concrete

Concrete for bridge decks is considered structural concrete. Therefore, in addition to the various requirements outlined in *Contract Specifications*, Section 90, *Concrete,* the concrete for bridge decks must comply with *Contract Specifications*, Section 51-1.02B, *Concrete Structures – General – Materials – Concrete.*

Cracking on a bridge deck is a significant concern, as it can lead to increased maintenance and reduced life span of the bridge. Requirements aimed at minimizing the risk of cracking on concrete bridge decks are included in the specifications. *Contract Specifications*, Section 51-1.02B specifies adding certain materials to the concrete mix for bridge decks, specifically polymer fibers and shrinkage reducing admixture. The required dosages of each are detailed in the relevant specification. The shrinkage limitations noted in *Contract Specifications*, Section 90-1.02A, *Concrete – General – Materials – General* may apply, depending on the amount of shrinkage reducing admixture used.

Likewise, the specified curing method for bridge decks differs from that of other bridge elements and concrete structures. *Contract Specifications*, Section 51-1.03H, *Concrete Structures – General – Construction – Curing Concrete Structures,* outlines the curing method and is discussed later in this chapter.

Concrete containing fibers, such as bridge deck concrete, has the potential to clump and may require pumps to work harder to convey during placement. The Contractor should take such potential issues into consideration when developing a mix design for the bridge deck.

7-8 Deck Concrete Placement

Effective bridge deck concrete placement requires detailed planning and coordination. This section of the chapter adds to the discussion in Chapter 5, *Concrete,* as it covers topics related to concrete placement specifically for bridge decks.

Review the Contractor’s authorized deck placement work plan and verify that they comply with the plan throughout the concrete pour. As mentioned previously, it is advisable to hold a preconstruction meeting with the Contractor before deck concrete placement. Discuss their work plan and question if there will be any deviations from the plan. Modifications may be necessary if site conditions are different than what was expected earlier in the project. If they are contemplating deviations, consider requesting the Contractor to resubmit their bridge deck placement work plan.

In addition to the work plan, topics to discuss should include implementation of their concrete quality control (QC) program, pour start time, adequate lighting, worker and public safety, traffic control, potential need for lights, and crews who are able to work an extended shift if necessary. Refer to *Contract Specifications*, Section 90-1.01D(10)(b), *Concrete – General –Quality Assurance – Quality Control – Cast-In-Place Structural Concrete Members,* and Chapter 2, *Preconstruction Planning*, for requirements and practices regarding the Contractors concrete QC program.

7-8.01 Concrete Delivery

7-8.01A Delivery Equipment

For typical CIP bridge construction projects, concrete is usually batched from an outside batch plant and delivered to the job site by truck mixers. Less frequently used concrete delivery methods, such as truck agitators, open-top vehicles, barges, etc., may be warranted if more suitable for schedule or site conditions.

7-8.01B Delivery and Pour Rate

A primary key to a successful pour is preparation that will result in a well-scheduled start and maintain a constant delivery rate. Since the rate of concrete delivery and placement affects the finishing operation, the Contractor should consider the following factors when planning the frequency that concrete is to be delivered:

1. Total theoretical quantity and expected delivery rate for the concrete placement.
2. Number of concrete pumps or concrete buckets and cranes.
3. Number and spacing of concrete trucks assigned to the concrete pour.
4. Method of concrete delivery at the concrete pump hopper.
5. Concrete pump capability to reach all areas of the pour, avoiding overhead hazards and suspended loads over traffic.
6. Possible need to relocate the concrete pump(s).
7. Potential impacts from local traffic (e.g., rush hour, start or end ~~of~~ times of nearby schools, accidents, sporting events, etc.).

Once the concrete pour timing and estimated duration are determined, some issues to discuss with the Contractor include:

1. Start time
2. Adequate lighting
3. Safety and traffic control
4. Safe access and facilities for concrete sampling and testing by QC personnel and SC staff.

The following is an example scenario of a potential issue related to pour rate:

> *The Contractor plans to place 600 cubic yards (CY) at 45 CY per hour. This means that the pour will take more than 13 hours to complete. If the pour begins at 7:00 a.m., the Contractor will finish placement and strike off around 8:30 p.m.*
>
> *The Contractor informed SC staff that they requested five trucks per hour from the concrete batch plant but could only secure four. However, the batch plant has assured the Contractor that four trucks will be sufficient since each truck carries almost 10 CY of concrete.*
>
> *During previous pours, SC staff observed that a full concrete truck commonly required approximately five minutes to discharge, 30 minutes to travel to the plant, 10 minutes to charge the mixer at the plant, and 30 minutes to travel back to the jobsite. As a result, the total time for a full truck to complete a round is about 75 minutes.*
>
> *To achieve a pour rate of 45 CY hour, the Contractor needs 4.5 trucks per hour, or about one truck about every 14 minutes. However, to maintain a steady rate of pour, consider the 75-minute round trip cycle time. Dividing this cycle time by the 14-minute pour rate yields 75/14 = 5.4 trucks, or six trucks to ensure an adequate amount of material delivery.*
>
> *SC staff must communicate to the Contractor that, based on the information provided, at least six trucks will be required to maintain a 45 CY per hour pour rate.*

Increased mechanization and decreased use of manual methods have allowed deck pours to proceed at a rate set by the capacity of the finishing equipment and the rate of delivery rather than by the crew’s physical limitations. Therefore, pour rates can be reduced to mathematical calculations (with some allowances for mechanical malfunctions) with little allowance for the “human factor.”

Before the pour, mark 10-foot stations along the edge-of-deck handrails, walkway, temporary concrete barrier (if used), or other convenient location and perform a theoretical volume calculation. Use these marks and volumes to track the production rate during the deck pour. This calculation should be done periodically during the pour to fine-tune the estimated time of completion, document the actual quantity of material used, as well as identifying any potential under-run of material that would otherwise necessitate a “cleanup” truck.

7-8.02 Conveyance and Placement

For bridge deck pours and most other concrete pours, concrete is typically placed starting from the low side and progressing uphill. Doing so enables the Contractor to better control concrete placement and travel of the bridge deck finishing machine.

Contractors have tried several different methods of placing concrete during deck pours. Some of the successful methods to date are the use of buggies, conveyor belts, pumps, and buckets. Concrete buckets and pumps are the two most common methods.

7-8.02A Concrete Buckets

Two buckets are typically used for the crane-and-bucket method. Assume an average pour rate of 45 cubic yards per hour when using one crane with two, 1 cubic yard buckets. While the crane is maneuvering and placing the first bucket, the second bucket is being filled. This approach ensures continuous placement of fresh concrete to the pour front.

Contractors often prefer using concrete buckets for pouring small deck spans. Other reasons include ownership of the bucket and crane, as well as the ability to maintain a slower, more controlled pour rate.

Some advantages of using the crane-and-bucket method include:

1. The crane can be used on other phases of work, eliminating the need for special equipment and setup.
2. The crane has a high degree of mobility, allowing concrete placement under difficult conditions.
3. A homogeneous mix is assured in most cases.

Some disadvantages of using the crane-and-bucket method include:

1. There may be areas outside of the crane’s reach that cannot be accessed for the pour.
2. Safety issues may arise from swinging booms during high pour rates, potentially requiring additional cranes.
3. Overhead wires that may be adjacent to or over the pour pose serious potential hazards.
4. The crane may need to boom over traffic, which is not allowed.
5. Impact due to concrete dropping from a high bucket can cause forms to fail.

When the bucket method is used, the Contractor must contain potential spills as the bucket is being filled with concrete and keep the bottom of the bucket frame and boot out of the dirt.

7-8.02B Concrete Pumps

Concrete pumps are the most popular and reliable method for placing deck concrete. Reasons why contractors use the concrete pump method include:

1. Concrete can be delivered at a more constant rate.
2. Pumps can reach farther than a crane.
3. Less labor is required for conveying concrete since the pump does the work.

Cranes with buckets and other previously used concrete conveyance methods are generally limited to receiving concrete at one or two locations. In contrast, pumps are mobile and can quickly change locations. Concrete pumps can place concrete in difficult to reach locations. This is very important for keeping a fresh pour front for deck concrete placement.

As mentioned in Chapter 5, *Concrete*, concrete pumps have advantages where overhead space is congested with utility lines or other obstructions because it requires less headroom. Pumps, in general, are less hazardous than cranes since there is no need for crew to handle or work around heavy swinging buckets.

As mentioned earlier, be aware of possible clumping of the bridge deck concrete containing fibers. This may cause issues with the pump during the pour.

7-8.03 Consolidation

Concrete presents a dry, irregular surface before being consolidated. In contrast, consolidated concrete appears moist once the fine aggregates rise and the large aggregates settle. The Contractor must initially consolidate deck concrete as it is placed immediately in front of the finishing operation, which is typically performed using internal vibrators (see Figure 7-27).

The operator's technique should vary with the depths and complexity of each section. In deep sections where it is possible for the vibrator to be inserted close to full depth, the operator must insert the vibrator into the concrete approximately every 2 feet and make sure the head enters almost vertically. In deck slabs where vertical insertion is not feasible, the vibrator should be inserted near horizontal to immerse the vibrator.

Figure 7-27. Vibrating Concrete on a Deck Pour

The vibrator should not be dragged horizontally over the top of the concrete surface, nor should it run continuously in a stationary position without the operator's full attention. Doing so can prevent the fine and large aggregates from settling properly, resulting in a non-homogenous deck cross section. Material in this condition leads to added maintenance and costs over the life of the deck.

Typical deck finishing machines are equipped with tamper rolling drums attached to the carriage. The rolling drums consolidate the top concrete surface as the carriage moves transversely during the finishing activity.

7-8.04 Bridge Deck Pour Inspection

Forms and surfaces that will be in contact with fresh concrete must be wet; however, do not allow water to pond, as this is prohibited. The consistency of concrete must be maintained and placed uniformly in front of and parallel to the finishing machine. The concrete must be adequately consolidated but not overly vibrated. Continuously check reinforcing steel clearances. Any displaced steel must be repositioned, blocked, and tied. Broken dobies also must be replaced.

Check that the Contractor is following their authorized concrete QC program, including sampling and testing as required. Likewise, SC staff must be diligent in performing all required concrete quality assurance testing.

Verify the position of waterstops, deck drains, manholes, conduit, prestressing hardware and accessories. They will need to be repositioned if they have been displaced.

During the pour, be mindful of how far ahead the Contractor is placing the concrete with respect to the finishing. If placed too far ahead, the concrete may begin to set prematurely, leading to issues during the finishing. Additionally, verify the actual deck depths by stabbing the plastic concrete following strike-off. Figure 7-28 illustrates the use of a snap tie marked at the deck thickness, a common tool used for checking depth.

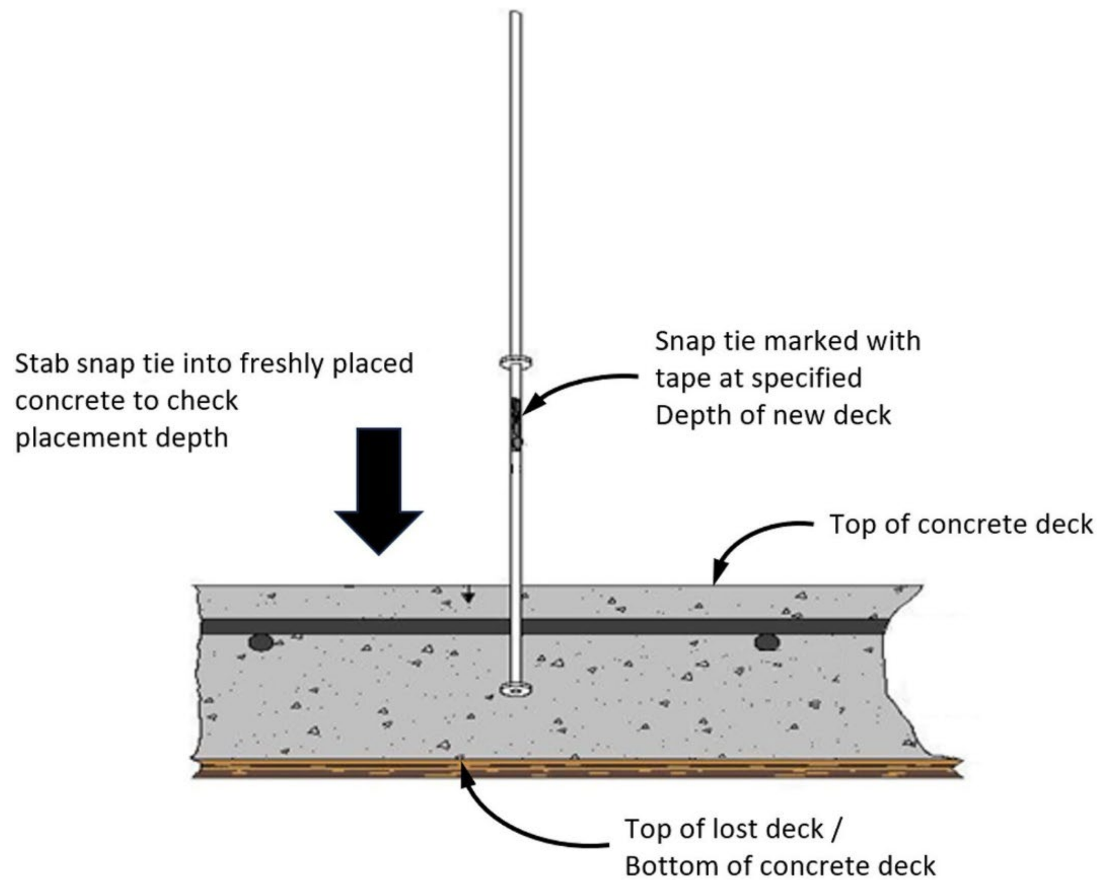

Figure 7-28. Improvised Snap Tie Depth Gauge

As stated in Chapter 6, *Bridge Construction Practices for Cast-In-Place Bridges*, the portion of the bridge deck surface where concrete barriers will be constructed is considered a construction joint. As such, the surface must be prepared per *Contract Specifications*, Section 51-1.03D(4), *Concrete Structures – General – Construction – Placing Concrete – Construction Joints.* This requires an irregular, or roughened surface, at the deck/barrier interface as well as removing laitance, curing compound, and other foreign material. Providing a 1/4-inch amplitude surface, although not required, would be ideal.

7-9 Finishing Roadway Surfaces

The requirements for a finished concrete bridge deck are in *Contract Specifications,* Section 51-1.03F(5), *Concrete Structures – General – Construction - Finishing Concrete – Finishing Roadway Surfaces*. Additional information is available in BCM 51-1.01, *Concrete Structures – General,* and BCM 51-1.03F(5-6), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Roadway and Pedestrian Overcrossing Surfaces.*

The deck finishing operation should be planned and carried out to minimize the need to apply water to the deck surface. Excessive water applied to the surface, either while finishing is in progress or after finishing is completed but before application of the cure, will increase the water-cement ratio at the surface, which may accelerate the deterioration of the wearing surface.

While air-entraining admixtures improve workability, they may also reduce the rate at which bleeding occurs. This may adversely affect the deck finishing operations. In hot weather conditions, particular emphasis should be placed on keeping the temperature of the concrete mixture as low as practicable and minimizing the indiscriminate use of water to increase workability or to facilitate finishing.

Bridge deck surfaces must meet a minimum measured coefficient of friction. Historically, achieving this requirement has been left to the Contractor's means and methods and was usually agreed to by SC staff. Previously, a coarse broom or transverse tined finish was commonly used on bridge decks. Since only minimal friction was required, some of these surface textures developed relatively deep grooves, which could lead to increased tire noise caused by high-speed vibrations as tires engaged the surface texture. Noise would be further amplified by the resonance of the bridge.

The Department has conducted research that has led to the current specifications. *Contract Specifications,* Section 51-1.03F(5)(b), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Roadway Surfaces – Bridge Deck Surface Texture,* requires bridge decks to be textured longitudinally. The texture is intended to produce a lesser amount of noise compared with the previous methods while still achieving the required coefficient of friction. BCM 51-1.03F(5-6), Attachment 1, *Quieter Bridge Deck Construction,* explains the development of the current surface texture specification. Additional historical context and references related to the surface texture specification can be found on the SC webpage[1] under the "Field Resources" tab, through the "Quieter Bridge Deck References" link.

[1] Caltrans internal use only

Contract Specifications, Section 40-1.03H(3), *Concrete Pavement – General – Construction – Finishing – Final Finishing,* requires an initial texture before the final longitudinal texture. As mentioned earlier, the burlap drag produces the required initial texture when using a bridge deck finishing machine.

The specification prescribes two methods for producing the final longitudinal tining on bridge decks:

1. Grinding and Grooving
2. Longitudinal Tining.

The requirements for grinding and grooving are detailed in *Contract Specifications*, Section 51-1.03F(5)(b)(ii), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Roadway Surfaces – Bridge Deck Surface Texture – Grinding and Grooving*. For grinding and grooving, the longitudinal texture is produced by using grinding machines that are configured to grind 12-foot-wide freeway lanes in 3 to 4-foot passes, as shown in Figure 7-29. Figure 7-30 shows the resulting deck after the grinding machine has passed.

Figure 7-29. Grinding Machine Grooving a Bridge Deck

Figure 7-30. Close-up Illustration of Grooved Deck

There may be irregular areas, such as between the barrier and the last pass of the machine, where it is difficult to groove a portion of the deck depending on the bridge geometry. The Contractor may suggest alternative means of providing the required texture at these locations, such as hand-constructing grooves or using multiple saws with walk-behind.

The deck surface must be ground and grooved to within 18 inches of the toe of the barrier. As mentioned earlier, to accommodate for the concrete that will be removed during grinding and loss of cover, an additional 1/4 inch of sacrificial concrete must be placed during the bridge deck concrete pour.

The requirements for longitudinal tining are located in *Contract Specifications*, Section 51-1.03F(5)(b)(iii), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Roadway Surfaces - Bridge Deck Surface Texture – Longitudinal Tining*. Longitudinal tining involves texturing the top surface by dragging a series of steel rakes or similar steel tining devices in the longitudinal direction. This process is done while the concrete is still plastic, but somewhat fluid, after it is struck off to the proper elevation and floated, and just before the application of the mist cure.

For concrete bridge decks, tining is often performed using a work bridge that follows the bridge deck finishing machine. The work bridge may have tining devices attached to its trailing end, as shown in Figure 7-31, or workers may stand on the work bridge and texture the surface with rakes as the work bridge moves. Figure 7-32 is a closeup view of a concrete deck being tined.

When longitudinal tining is the selected method, both the Contractor and SC staff should continually check the condition of the rakes. The use of fiber reinforcement can lead to accumulation of material between the tines, potentially resulting in gouges in the deck. In severe cases, errant or damaged tines may hook and drag coarse aggregate, similarly resulting in gouges in the deck surface. Early detection of these issues can significantly reduce the amount of corrective hand finishing.

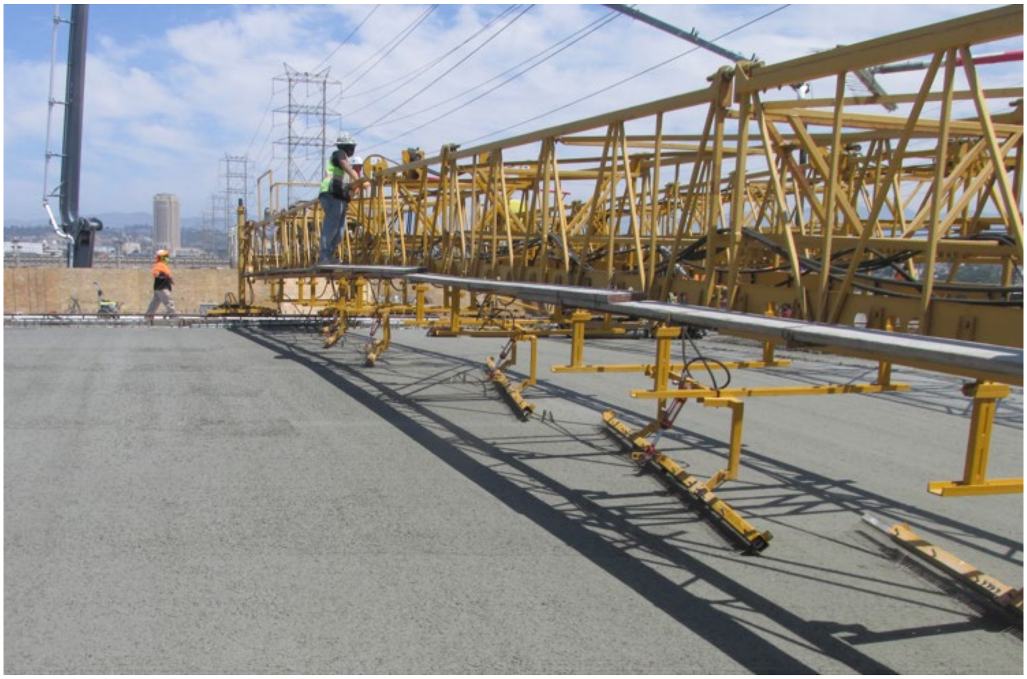

Figure 7-31. Longitudinal Tining from a Work Bridge

Figure 7-32. Longitudinal Tining

7-10 Curing Bridge Decks

Due to its large, exposed surface and its importance in contributing to the service life of a bridge, the requirements for curing a bridge deck are demanding. These requirements can be found in *Contract Specifications,* Section 51-1.03H, *Curing Concrete Structures*.

Once the deck is finished to the proper elevation and texture, the top surface must be kept continually wet by an atomized mist, as shown in Figure 7-33. Afterwards, for a full 7 days, the deck must be cured via the water method by using a curing media, in accordance with *Contract Specifications,* Section 90-1.03B(2), *Concrete – General – Construction – Curing Concrete – Water Method.* Contractors typically use curing blankets, placing them when the concrete is hard enough.

As specified, the Contractor must continue to apply the atomized mist until the deck is covered with the curing media. To prevent the curing media from drawing moisture from the deck, good practice is for the Contractor to pre-wet the curing media before use. Check regularly that the bridge deck is kept wet throughout the 7-day cure period. The Contractor will likely have to reapply water to keep the curing media wet until they are allowed to remove the curing media. This requires the Contractor to schedule staff to work during a weekend to monitor and rewet as necessary. Verify regularly that the curing media is wet throughout the 7 days, as seen in Figure 7-34, and inform the Contractor if they need to reapply water.

Figure 7-33. Application of Atomized Mist on Bridge Deck

Figure 7-34. Wet Curing Blankets

At the end of the 7-day curing period, the Contractor must remove the curing media and apply a uniform coat of pigmented curing compound. Before use, the curing compound material must be accepted by the Department. Chapter 5 details practices for accepting and applying curing compound.

Although not specified, there may be unforeseen situations when SC staff could consider permitting the Contractor to apply curing compound before starting the 7-day water curing process. Such situations might include malfunctions of the misting equipment or adverse environmental conditions, such as extremely high winds. Exercise engineering judgment when evaluating the need for allowing an out-of-sequence curing procedure. Discuss this potential course of action with the Contractor to ensure they are prepared to proceed if required.

Monitor the surface temperature of the deck, particularly during hot weather. Bring to the Contractor’s attention if the surface temperature exceeds the allowable for water cure (140 ºF), as they may have to propose alternative curing methods. Additionally, *Contract Specifications,* Section 51-1.03I, *Concrete Structures – General – Construction – Protecting Concrete Structures,* requires maintaining minimum concrete temperature during the curing period.

For bridges requiring epoxy-coated reinforcement for concrete barriers, be aware that curing compound sprayed and left on the epoxy-coated reinforcement will negatively affect the bond between the reinforcement and barrier concrete. Curing compound on epoxy-coated reinforcement should be removed as soon as possible, taking care not to damage the coating. Other means for curing the bridge deck after the 7-day water cure method at the barrier areas can be discussed with the Contractor.

7-11 Testing Roadway Surfaces

The Department determines the acceptability of bridge deck surfaces based on three criteria noted in *Contract Specifications*, Section 51-1.01D(3)(b), *Concrete Structures – General – Quality Assurance - Department Acceptance – Testing Concrete Surfaces*:

1. Surface smoothness
2. Coefficient of friction
3. Crack intensity.

Except for coefficient of friction, SC staff performs acceptance testing to verify the acceptability of the above criteria.

7-11.01 Surface Smoothness

The smoothness of a roadway, including bridge decks, indicates its rideability and comfort for travelers riding on the traveled surface. A rough traveling surface will contain noticeable and/or multiple “humps” on the road, whereas a smooth one will have minimal. *Contract Specifications,* Section 51-1.01D(3)(b)(ii), *Concrete Structures – General – Quality Assurance – Department Acceptance – Testing Concrete Surfaces – Surface Smoothness,* lists the requirements of what is considered a smooth riding surface. It also specifies the test methods to be used. The requirements for a pedestrian overcrossing (POC) are discussed later in this chapter. The Contractor shall request testing at least 10 days prior to need and must ensure that the entire area to be tested has been cleared and cleaned of all obstructions.

For typical bridge decks, SC staff uses a bridge profilograph to test the surface along the longitudinal direction, and a 12-foot-long straightedge for testing along the transverse direction. The straightedge can also be used to verify non-compliant locations that were found using the profilograph. California Test 547, *Method of Test for Operation of Bridge Profilograph and Evaluation of Profiles,* provides instructions for using a bridge profilograph to test roadway smoothness (see Figure 7-35).

Furthermore, SC has a Profilograph video[1] to review the assembly and use of this item.

Figure 7-35. Smoothness Testing per California Test 547

SC staff marks with paint the non-compliant high points on the bridge deck. As mentioned in Chapter 6, the Begin Bridge (BB) and End Bridge (EB) are locations likely to not comply with the smoothness requirements.

As soon as possible after surface smoothness testing, write and transmit a letter to the Contractor advising that the deck has been checked for compliance with the requirements. The letter should describe the specific locations that fail to meet the straightedge specifications or describe any deficiencies in meeting the profilograph specification. The letter should state that the specific deficiencies must be corrected before the contract can be accepted. After the deficiencies have been corrected, or if the entire deck initially complies with the applicable requirements, then write and transmit to the Contractor a letter stating that the deck was checked and that it complies with the profilograph requirements and/or the straightedge requirements, whichever is applicable.

See Section 7-11.01A, *Sample Letter #1* below for a sample portion of a letter relative to concrete decks or concrete approach slabs which are to be covered with one inch or more of another material. See Section 7-11.01B, *Sample Letter #2* below for a sample portion of a letter relative to the completed surfaces of bridge decks, approach slabs, and adjoining 50 feet of approach pavement.

[1] Caltrans internal use only

Deck grinding is an acceptable means to improving deck profile and smoothness, hence the term “must grind” given to non-compliant high points. However, it is not without its problems. Grinding reduces the cover over the deck rebar and degrades the finished surface, leaving fractured aggregate particles exposed to the elements. This is particularly harmful in areas subject to freeze/thaw cycles and the application of de-icing salt. Deck grinding is not a complete solution for bridge deck surface issues that careful planning and execution during the deck pour can prevent.

7-11.01A Sample Letter #1

The finished surface of the deck concrete at ________________________________
Bridge No.______ has been tested for compliance with the straightedge requirements in Sections 51-1.01D(3)(b)(ii), *Concrete Structures – General – Quality Assurance – Department Acceptance – Testing Concrete Surfaces – Surface Smoothness,* and 51-1.03F(5)(a), *Concrete Structures – Construction – Finishing Concrete –Finishing Roadway Surfaces – General,* of the *Contract Specifications*.

(USE EITHER)

All areas tested were found to comply with the specified straightedge requirements.

(OR)

Areas that do not meet the straightedge requirements have been marked, and are located as noted below:

(EXAMPLES) Sta. 300+52 (5 ft to 15 ft from Right EOD)

Sta. 301+60 (10 ft from Right EOD)

Hinge in Span 3 (Entire bridge width)

Transversely across longitudinal construction joint (Sta. 300+10 to 302+10)

These deficiencies must be corrected before the ______________________________
overlay is placed. (describe overlay)

Notification must be given to the Resident Engineer prior to performing the corrective action.

7-11.01B Sample Letter #2

The completed surface of <bridge deck> <approach slab> <adjoining 50 feet of approach pavement> at Bridge No. ________, Bridge Name ____________________ has been tested for compliance with the profilograph requirements and the transverse straightedge requirements of Sections 51-1.01D(3)(b)(ii), *Concrete Structures – General – Quality Assurance – Department Acceptance – Testing Concrete Surfaces – Surface Smoothness* , and 51-1.03F(5)(a), *Concrete Structures – Construction – Finishing Concrete –Finishing Roadway Surfaces – General,* of the *Contract Specifications*.

(USE EITHER)

All areas tested were found to comply with the specified profilograph (and) (or) the transverse straightedge requirements.

(AND/OR)

The profilograph trace indicates that there are high points in excess of 0.02 foot and that the profile count exceeds 5 per hundred feet. High points in excess of 0.02 foot have been marked with spray paint. A profile trace is available for your examination at the Resident Engineer's office. The completed surface must be ground in accordance with the requirements in *Contract Specifications,* Section 42, *Groove and Grind Concrete*, until the specified smoothness tolerances are met.

(AND/OR)

Straightedging in a transverse direction indicated that the roadway surface varied more than 0.02 foot from the lower edge of a 12-foot long straightedge at the following locations:

Areas that do not meet the straightedge requirement have been marked, and are located as noted below:

(EXAMPLE) 4 feet from the left EOD between Sta. 300+00 and Sta. 300+75.

Longitudinal construction joint at center of left bridge between Sta. 300+50 and Sta. 301+10.

These deficiencies must be corrected before the contract can be accepted. Notification must be given to the Resident Engineer prior to performing the corrective action.

7-11.02 Coefficient of Friction

The friction between vehicle tires and roadway surfaces is crucial, as it provides grip for tires to prevent vehicles from skidding. Friction is particularly important when the roadway is wet or icy. The coefficient of friction is a measurable value that indicates the amount of friction between objects. *Contract Specifications*, Section 51-1.01D(3)(b)(iii), *Concrete Structures – General – Quality Assurance – Department Acceptance – Testing Concrete Surfaces – Coefficient of Friction,* requires bridge deck surfaces and approach slabs to have a coefficient of friction of not less than 0.35.

After the deck surfaces and approach slabs have been textured, the deck surface will be tested for the coefficient of friction of the concrete surface under California Test 342, *Method of Test for Surface Skid Resistance with the California Portable Skid Test*. The test must be performed at a location which is representative of that portion of the deck surface exhibiting the lowest coefficient of friction. Once the representative area has been tested and shown to meet the specifications, more tests will not be required unless, in the opinion of the Structure Representative, the test results are not representative of the bridge deck skid resistance.

To meet the 25-day allowance in the *Contract Specifications* for coefficient of friction testing and to ensure that there are no delays to the contract, the tests will have to be scheduled as soon as possible. Coefficient of friction testing through METS can be arranged by contacting the appropriate staff listed on the instruction tab of the *Request for Portable Skid Test Form*[1]*.* Instructions for viewing the Skid Testing group's schedule are also included. Instructions for requesting skid testing services through METS Data Interchange for Materials Engineering (DIME) website can be found in the METS Office of Quality Assurance & Source Inspection (OQASI)[1] website. Figure 7-36 shows skid testing being performed. Skid testing can also be performed by the local District Laboratory. The process for requesting testing varies for each District.

SC staff witnessing the skid test must verify that the skid test machine has a valid calibration under California Test 114, *Method of Test for Calibration of California Portable Skid Tester*.

[1] Caltrans internal use only

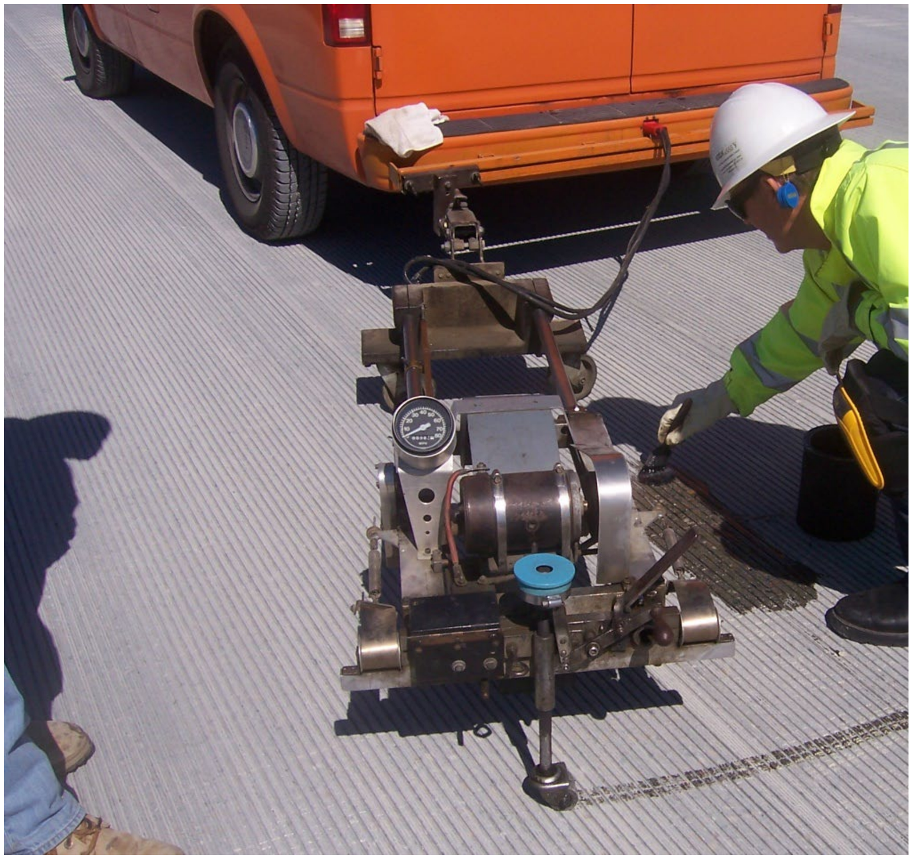

Figure 7-36. Coefficient of Friction (Skid) Testing per *California Test 342*

Deck and approach slab portion surfaces not meeting the minimum coefficient of friction must be ground or grooved.

7-11.03 Crack Intensity

Crack intensity is the visual measure of the amount of surface cracks that exceed the maximum allowable width. *Contract Specifications,* Section 51-1.01D(3)(b)(iv), *Concrete Structures – General – Quality Assurance – Department Acceptance – Testing Concrete Surfaces – Crack Intensity,* limits the cumulative length of cracks that exceed 0.02 inches within a specified area. The length and area depend on the type of bridge deck, as noted in the specifications.

A visual crack comparator shown in Figure 7-37 is commonly used for this purpose. A feeler gauge may also be used. A very close approximation to 0.02 inches is the 0.5-mm pencil lead of a common mechanical pencil. If any areas are found to be non-compliant, the bridge deck must be treated with methacrylate resin to address the issue.

Figure 7-37. Crack Width Measurement with a Crack Comparator

While performing crack intensity assessments, maintain concise records and mark the deck to readily identify any areas requiring mitigation or further evaluation.

7-12 Pedestrian Overcrossings

Pay special attention to the deck construction of POCs and similar pedestrian bridges and facilities. In addition to *Contract Specifications*, Section 51-1.03F(6), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Pedestrian Overcrossing Surfaces*, POC walkways must also comply with American with Disabilities Act (ADA) requirements. ADA standards establish guidelines for pedestrian facilities, including minimum clear width, texture finish, running (or profile) slope, and cross slope. The latest Design Information Bulletin (DIB) 82*, Pedestrian Accessibility Guidelines for Highway Projects*, provides design guidance for permanent pedestrian facilities.

POCs must be designed so that the walking surface – namely the bridge deck – complies with ADA requirements. However, several factors may hinder compliance, and these potential issues may not always be accounted for by the BD Project Engineer. Review the contract documents during the early stages of the project, taking into consideration ADA compliance. This is best done during the project development stage, so that design oversights can be addressed before the project is finalized.

Discuss issues identified with the BD Project Engineer. Pay particular attention to factors that may negatively affect the profile slope, as the POC design may not have accounted for design features and other potential issues that could cause the constructed deck to exceed ADA limits for running slope. Obtain the maximum allowable running slope limit from the designer. Then consider the following when reviewing the contract documents:

1. Construction Allowances (Tolerances) and ADA Compliance – The design profile of the POC may be significantly close to the ADA limit when considering construction tolerance. Caltrans ADA Compliance Inspection Report forms consider 0.2 percent as the allowable construction tolerance for slopes. Note that the accuracy of specified measuring devices is accounted for in the allowable tolerances.
2. Bridge Camber Impact on Profile Slope – For a bridge span that slopes uphill, the long-term design bridge camber typically increases from the low end toward mid-span. The addition of the increasing design bridge camber causes the as-constructed profile slope to be steeper than the design profile slope for this portion of the span. This may result in portions of the deck exceeding the ADA running slope limit when constructed, as shown in Figure 7-38. Even after falsework removal, residual camber may still impact the profile at the time of bridge opening.

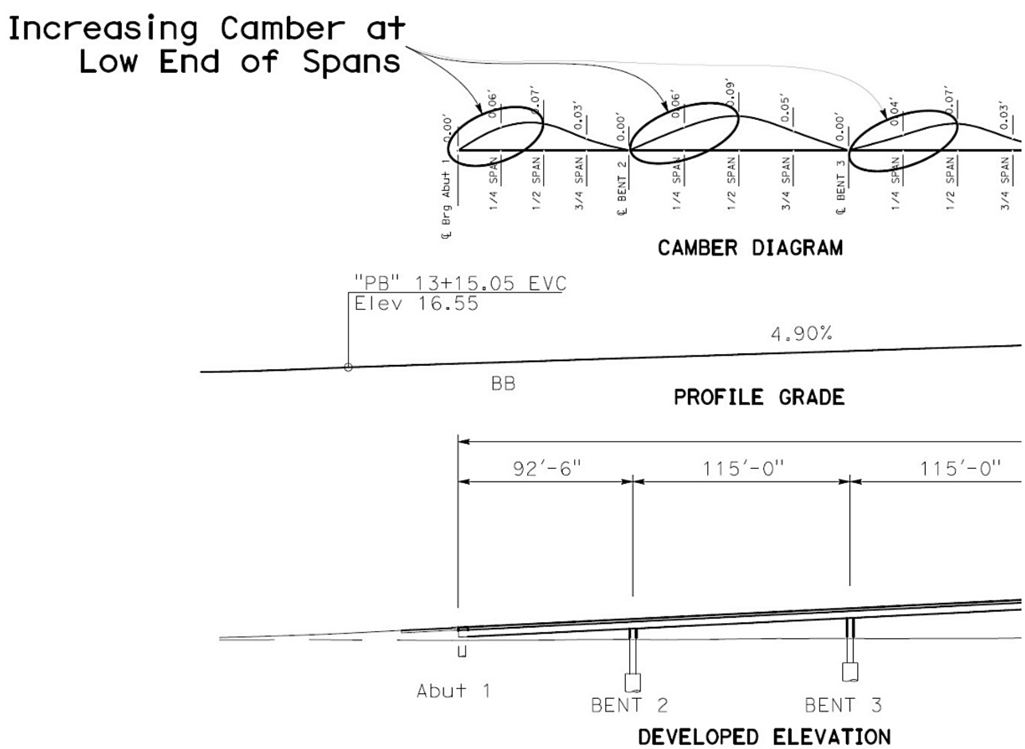

Figure 7-38. Increasing Long-Term Camber Increases Constructed Profile

3. The profile shown in the project plans is typically at the bridge centerline with the cross slope being consistent along horizontal curves. Due to the geometry of horizontal curves, the profile slope increases from bridge centerline moving transversely towards the inner curve. This is because the curve length decreases when moving towards the inner curve, while the elevation change stays consistent. Conversely, the profile slope decreases from bridge centerline to outer curve, as the curve length increases while the elevation change still stays consistent (see Figure 7-39).

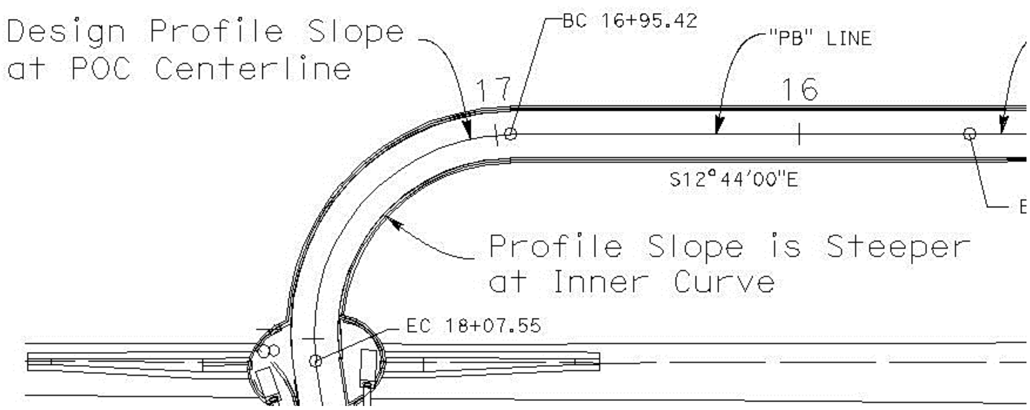

Figure 7-39. Profile Slope is Steeper at Inner Curve

Methods of deck construction and inspection for POC bridge decks are similar as those for concrete bridge decks. However, due to the stringent ADA requirements, consider incorporating the below additional practices for POC deck construction:

1. To maximize grade control, place elevation control points (deck dowels) as reasonably close to the minimum allowable transverse distance as possible (4 feet transversely to the POC centerline). *Contract Specifications*, Section 51-1.03F(6), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Pedestrian Overcrossing Surfaces,* allows a closer transverse distance of control points for POCs compared with *Contract Specifications*, Section 51-1.03F(5)(a), *Concrete Structures – General – Construction – Finishing Concrete – Finishing Roadway Surfaces – General,* for roadway bridges (24 feet from centerline).
2. After the Contractor grades the screed rails, use a digital level to verify that the cross-slope and profile slope of the rails are close to the expected values (ensure that the digital level is calibrated per the manufacturer’s instructions).
3. Verify that objects built into or on the bridge deck, such as drain gratings, cover plates, and railings, are installed such that they will be ADA compliant.

Contract Specifications, Section 51-1.01D(3)(b)(ii), *Concrete Structures – General – Quality Assurance – Department Acceptance – Testing Concrete Surfaces – Surface Smoothness,* provides separate requirements and testing methods for deck smoothness of POCs and bridge decks. The smoothness of POC bridge decks is tested with a 12-foot-long straightedge in the longitudinal direction and a 6-foot straightedge in the transverse direction.

POC bridge decks are not required to meet a specified coefficient of friction. According to *Contract Specifications*, Section 51-1.03F(6), a broom finish surface texture is required. However, DIB 82 advises using "engineering judgment" to evaluate the acceptability of the walking surface for pedestrians. Regarding crack intensity, the requirements for POC bridge decks are the same as those for decks for vehicular bridges.

Before contract acceptance, the Resident Engineer is responsible for documenting that permanent pedestrian facilities comply with ADA requirements, using the appropriate ADA Compliance Inspection Report form. These forms are organized in a table within the *Documentation and Certification* section of the ADA Handbook described and linked to below. Assist the Resident Engineer in performing the appropriate measurements and documentation. Directions for measuring and documenting, including what tools to use and how often to measure, are included in the form. The *Permanent Pedestrian Facilities ADA Compliance Handbook* contains more thorough inspection checklists. Use the checklist that is most applicable.