CHAPTER 2: BRIDGE DECK FORMS

Constructing a bridge deck that is both structurally sound and durable requires careful planning and preparation. This chapter discusses specific details about essential elements of bridge deck construction and inspection.

2-1 Deck Construction

In the construction process, pay careful attention to construction details, structural adequacy, alignment and grading. The following essential elements are discussed in greater detail in this chapter:

1. Types of construction details.
2. Structural adequacy.
3. Vertical alignment and grading.
4. Horizontal alignment.

2-1.1 Types of Construction Details[1]

Deck construction centers around two types of finished forms:

1. Stay-in-place or lost-deck forming.
2. Exposed surface forms.

2-1.1.A Stay-In-Place or Lost-Deck Forming

By far the most common stay in place form system used for box girder bridge construction is known as a lost-deck form system. Although there are variations in forming methods and construction details, the general system of forming a typical box girder bridge deck is shown on Figures 2.1-1 and 2.1-2.

Figure 2.1-1. Typical Deck Form Support for a Concrete Box Girder Bridge.

[1] 2010 Standard Specification (SS), 51-1.03C(2), *Forms*.

Figure 2.1-2. Typical Deck Sheathing Supports on a Concrete Box Girder Bridge.

For typical cast in place structures the lost-deck forms/falsework that support the bridge deck concrete are typically comprised of sheathing, joists, ledgers, and possibly posts.

Sheathing can be either:

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

Sheathing should be mortar tight with all holes patched. In lieu of dutchmen patching, metal is sometimes used to cover small holes and gaps in forms to prevent mortar leaks. Metal and precast concrete stay-in-place forms, some having a structural significance in the final product, have been permitted on some projects (usually detailed on the contract plans or by Contract Change Orders [CCO]).

The sheathing sits atop the joists which are generally 4 x 4 or 2 x 4 material.

Ledgers support the joists and are typically supported by either:

- Posts.
- Rebar placed in the side of the girder stem prior to pouring, bars are generally #4, #5 or #6.
- Low velocity powder driven nails typically used to attach wood ledgers to concrete.

For precast or steel girder bridges it is common to see stay-in-place forms in locations where:

- The removal of the forming would be difficult.
- Would require additional time possibly adding a season to the work.
- Cause environmental impacts.

When stay-in-place forms are proposed via a CCO, it is important to gather input from

Structure Maintenance and Investigation (SM&I), as well as Structure Design (SD), as the girders may need to be checked for the additional dead load. See Figure 2.1-3 for an example of stay-in-place forms.

Figure 2.1-3. Stay-in-Place Metal Forming on a Precast Girder Bridge.

2-1.1.B Exposed Surface Forms

In deck construction, exposed surfaces refer to those surfaces that, when the forms are removed, the concrete surface will be visible. These surfaces include the edge of the deck, soffits of slab bridges, deck soffits for T-beam, steel girder, precast concrete girder bridges, and deck overhangs for all bridge types. In slab bridges, the plywood soffit forms are directly attached to and supported by the falsework joists or stringers and are considered an integral part of the falsework system (see *Falsework Manual*). Deck slab forms for T-beam, steel girder, and precast concrete girder bridges, and overhangs are usually of conventional joist and plywood construction. The bridge superstructure dictates the method of support for the forms. See Figures 2.1-4, 2.1-5, and 2.1-6 for examples of a slab bridge, a steel girder bridge, and a T-beam bridge. Figures 2.1-7 through 2.1-9 are construction details for each type of bridge superstructure. The bridge superstructure dictates the method of support for the form system.

Figure 2.1-4. Example of a Slab Bridge.

Figure 2.1-5. Example of a Steel-Girder Bridge.

Figure 2.1-6. Example of a T-Beam Bridge.

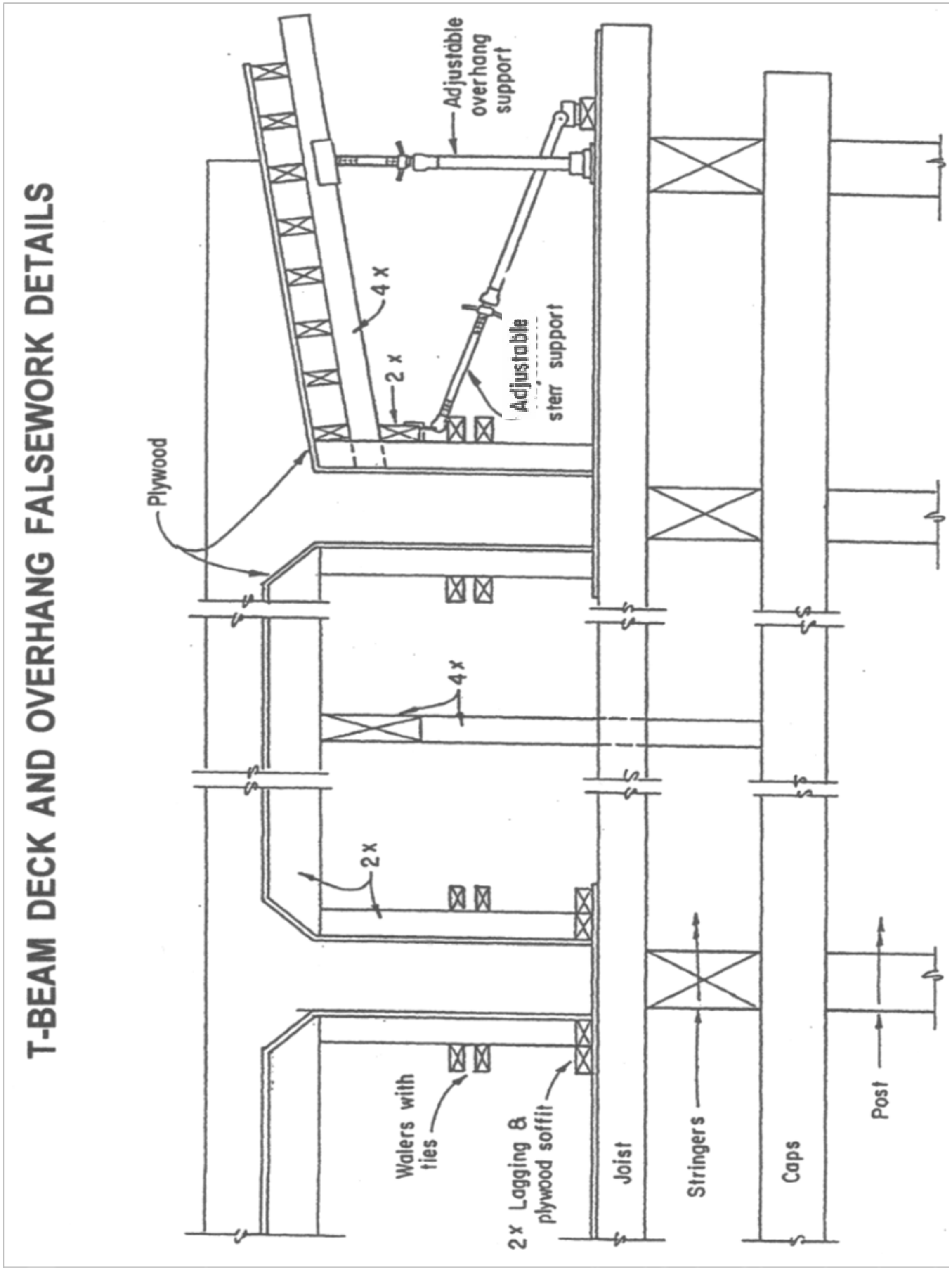


Figure 2.1-7. Sample T-beam and Overhang Falsework Details.

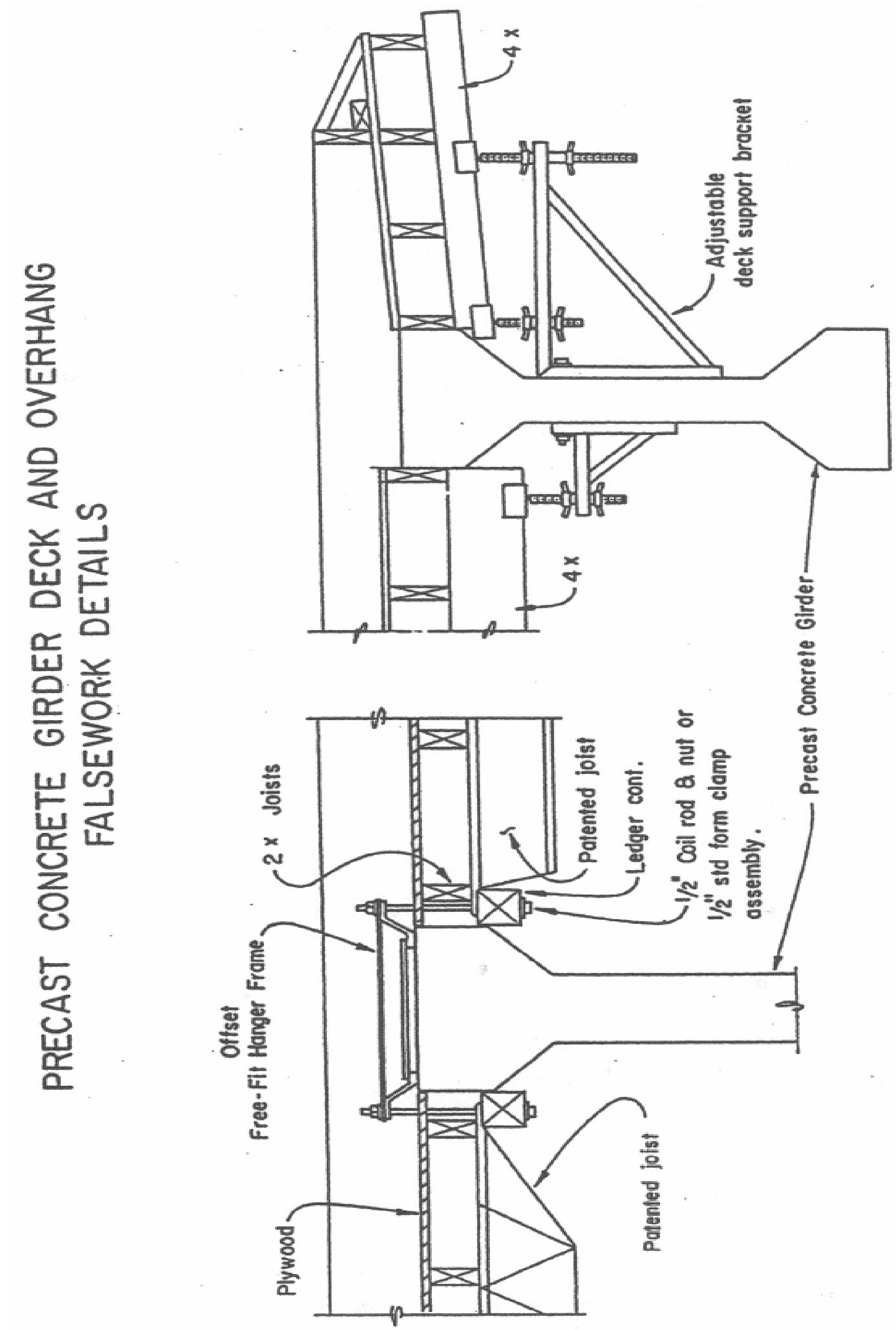
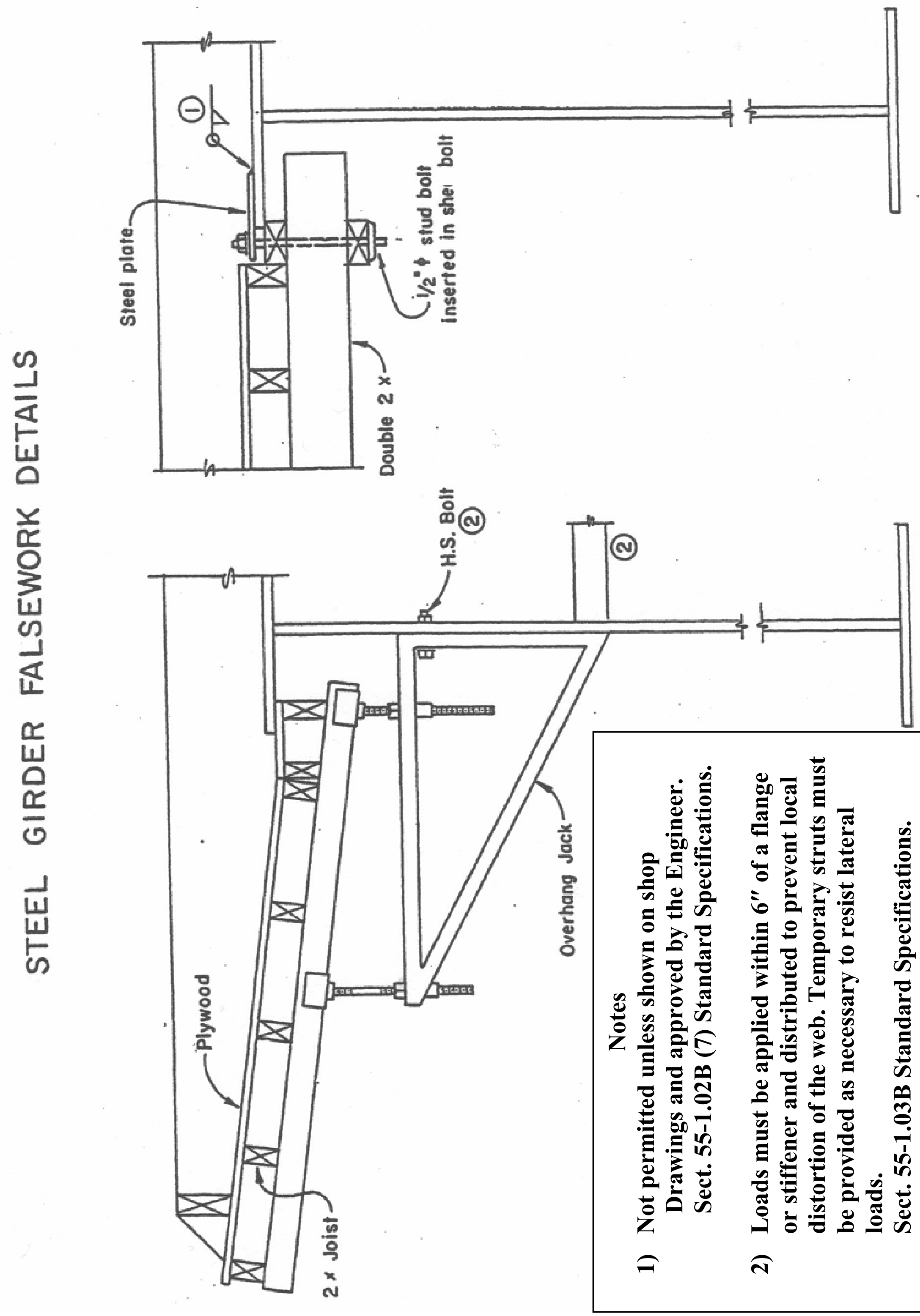


Figure 2.1-8. Sample Precast Concrete Girder Deck and Overhang Falsework Details.



Notes

1) Not permitted unless shown on shop Drawings and approved by the Engineer. Sect. 55-1.02B (7) Standard Specifications.

2) Loads must be applied within 6" of a flange or stiffener and distributed to prevent local distortion of the web. Temporary struts must be provided as necessary to resist lateral loads. Sect. 55-1.03B Standard Specifications.

Figure 2.1-9. Sample Steel Girder Bridge Falsework Details.

2-1.2 Structural Adequacy

Check the adequacy of all bridge deck forming systems by stress analysis, as they are considered part of the supporting falsework.[2] It should be noted, however, that form behavior cannot always be predicted or determined by analytical calculations of its load carrying capacity. If the physical properties and condition of the material are known, calculate theoretical deflections. In the case of lost-deck forms, the sheathing is frequently a material (plywood chip board), or grade of material, whose modulus of elasticity is questionable, particularly when the moisture content approaches the saturation point. Consequently, deflections may, and probably do, exceed some arbitrary value commonly accepted and known in industry as a *negligible amount*.

There is also evidence that deflections and joint take-up of the forms is not instantaneous, but continues, in some cases, beyond the initial set period of the concrete, resulting in noticeable surface cracking along the stems.

Deflection and settlement can and do occur after concrete placement. Normally, yielding of the forms is not structurally detrimental to the deck slab as long as the deflection does not continue after the initial set period. A uniform riding deck surface may not be achievable if the concrete subsides after form deflection and settlement.

The joists supporting the deck slabs of steel, precast concrete girder bridges, and deck overhangs are considered falsework. The sheathing deflections or undulations between joists, constituting forms for exposed concrete surfaces, are covered by the *Standard Specifications.*

The structural adequacy and deflection of timber joists is determined by stress analysis. If the manufacturer's loading data is in question, load test patented joists to determine the dead load deflection for the actual condition of loading.

Normally, ledgers support patented or timber joists for steel and precast concrete girder bridges. Ledgers are either underpinned by posts to the bottom flanges of the girders or suspended from the girders by hangers.

Use custom or homemade hangers (e.g. bar stock bent to form a "U" which fits over the top of the girders) only after they are satisfactorily load tested and approved by the Engineer. This method of fabrication creates high stress points at the bends, and use of this type of hanger has resulted in total failure under relatively light loads. For this reason, Structure Construction (SC) policy is to use half of the ultimate load carrying capacity of these hangers as the allowable load.[3] Many types of patented hangers are available for deck forming systems on either steel or precast concrete girder bridges. The safe working loads recommended by most manufacturers are based on, and subject to,

[2] 2010 SS, 48-2.01D(3)(a), *Quality Control and Assurance*, *Design Criteria, General*.
[3] Allowable or Working Load = Ultimate Load ÷ 2.

specific loading conditions, and any modification of the units themselves or deviation from their intended use will affect their load carrying capacity. The hanger bolts must be either flush with or a specified distance from the edges of the girder flange. The rated capacity of some hangers depends on whether they are used on steel or concrete girders. Investigate hangers for potential uplift and subsequent rotation issues due to unbalanced loading.

The forming system may provide restraint, or the hangers may be welded to the girders subject to the conditional requirements.[4] Do not weld or tack brackets, clips, shipping devices, or other material not described to any part of the girders unless shown on the shop drawings. On conventional steel girder bridges, the extension of the haunch or deck forms under the girder flanges affords restraint.

Figure 2.1-10. Overhang Post Supports Bearing Directly on the Falsework.

The falsework system supports overhang forms by underpinning soffit forms with posts (See Figure 2.1-10).

On steel and precast concrete girder bridges, overhang brackets or jacks attached to the exterior girder support the forms (as shown in Figures 2.1-8 and 2.1-9). Both systems are considered falsework and are analyzed as such.[5]

Construct falsework and concrete forms on steel structures such that loads applied to girder webs:

1. Are applied within 6″ of a flange or stiffener.
2. Do not produce local distortion of the web.

[4] 2010 SS, 55-102B(7)(a), *Welding, General*.
[5] 2010 SS, 55-1.03B, *Falsework*.

Provide temporary struts and ties to:

1. Resist lateral loads applied to girder flanges.
2. Prevent appreciable vertical movement between the edge of deck form and the adjacent steel girder.

When screed rails are located in the overhang area, deflection must be minimal for appearance and satisfactory grade control. Determination of deflection is difficult particularly when brackets or jacks with cantilevered joists or outriggers are used. If analysis or precedent cannot ascertain form behavior and deflection, a load test is justified.

Contractors widely use patented overhang brackets and jacks, such as those manufactured by:

1. Dayton Superior Concrete Accessories, Inc.
2. Waco Scaffold and Supply Company.
3. OCM, Inc.

Design information, including deflection data, for these units is available from the manufacturer and must be requested from the Contractor to check these products for contract compliance.

2-1.3 Vertical Alignment and Grading

Preconstruction planning is critical to vertical alignment and grading. The Contractor must determine and propose a deck framing system, the types of material to be used, where screed rails will be located (e.g. on the edge of deck forms), and how the forms will be adjusted. Discuss grading requirements and procedures at this time.

Control for lost-deck forms in box girder bridges is usually established on lost-deck dowels after the soffit and stem pour. Remove the girder forms and walkways used during the stem and soffit pour. They are usually used as lost-deck forms. When the walkways are removed, safe access to lost-deck dowels is also removed. The contractor must install adequate safety features to safely access the lost-deck dowels before establishing decks grades in the field.

The Engineer gives cuts to the top of deck. Provide a cut from the top of a rebar dowel cast in the girders at predetermined points to give adequate control for deck forming. The Contractor then determines the elevation of form supports. In some cases you may use a hacksaw to make a saw cut on the rebar dowel (or lost-deck dowel) at the top of the deck elevation at each dowel. Run a string line transversely across the deck to the lost deck dowel at the corresponding station (See Figure 2.1-11). The Contractor will move the string line along the length of the bridge from dowel sets to dowel sets and build lost-deck forms from this string line. Provide grades at all breaks in the grade and at intervals not closer than 8 ft longitudinally and 24 ft transversely to the centerline of bridge. A typical distance between lost-deck dowels is in 10-foot stations. If deck grading will be complicated, additional dowels may be necessary. Discuss dowel layout with the Contractor in advance. Consider the amount of vertical curve and camber when determining these intervals so that string lining between these points will not cut out camber or vertical curve. Refer to the *Falsework Manual* for more discussion on camber.

Figure 2.1-11. A String-Line Strung Between Deck Dowels.

Right after establishing deck grades, make a visual check at random locations to see how these grades correlate with what is already poured. To quickly visually assess deck grades, place tape at the saw cut on the lost-deck dowel. The tape must be consistently placed below the saw cut. This tape will provide a quick visual check, as well as a quick reference to locate saw cuts for later use:

1. Do the stirrup heights fit? (Check the length of the stirrup before the stem pour.)
2. Is the structural depth correct? Now is the time to consider any necessary grade adjustments, not after placement, when the deck steel is found to be not quite right.

Grade for the deck overhangs requires extra attention since these grades produce one of the more obvious lines of the structure. First, determine all grades at the locations where a grade adjustment is to be made. Field-measure the locations of the overhang supports and plot these on the 4-scale drawing or edge of deck profile line. Before grading 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 rebar is in place.

Many different schemes have been proposed for grading overhangs (e.g. grade every other support, grade it all 0.25″ low the first time then bring it up, etc...). Whatever method is used, always grade upward to the final elevation. Until the Contractor's system has been proven on the job, the Engineer should be prepared to check each location. The final check of the overhang is the "eye ball," but make sure to complete all final wedging and adjustments at the face of girders and the overhang. See Chapter 4, *Grade Control, Screeds and Bulkheads,* for a detailed discussion on grading overhangs.

2-1.4 Horizontal Alignment

The particular horizontal alignment of the specific structure under construction dictates the tools necessary to provide this line. Before the horizontal line is set on the edge of deck forms, the grade of these forms must be close. The Contractor can accomplish this rough grading with the use of templates and the lost-deck grade dowels.

Establish straight lines with a transit and/or string line. Establish curved lines with a transit and standard chord offset procedure using the centerline of abutments and bents as control points. On complex projects, get District Surveys Services involved.

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

1. Check into known points at each end of the structure.
2. Check the overall width at several locations throughout the length of the structure.

2-2 Inspection[6]

The inspection process affects the entire area encompassing the deck. From construction to overhangs and expansion joints, inspection assesses how the deck is built, any and all materials and artifices touching and associated with the deck, and the deck's impact on the overall surroundings.

The following are essential elements to consider for the inspection phase:

1. Structural adequacy, mortar tightness, and condition of surface.
2. Hinges, construction joints, paving notches, and approach slabs.
3. Overhangs.
4. Miscellaneous items–drains, conduit, etc.
5. Expansion joints.

2-2.1 Structural Adequacy, Mortar Tightness, and Condition of Surface

The structural adequacy of the forming system, as with falsework, is not determined solely on the basis of stress analysis. Inspection of the forms is necessary to ensure their stability. Personnel who are thoroughly familiar with the forming plans (i.e., the person who checked the falsework or someone who at least reviewed it) should perform the inspection.

Where appearance is important, mortar tightness and surface condition for the forms of exposed concrete surfaces is also important. Because the lost-deck is not visible, the subject of mortar tightness is often dismissed. Nevertheless, the Contractor must be directed to patch any lost-deck form hole greater than 0.25 in. and any spaces between

[6] See the *Field Construction Practices Manual* for additional guidance.

fillet and deck soffit. Loss of mortar or grout through holes or cracks in the forms affects the appearance of the concrete, as well as its structural quality. Tin is often used to patch holes or cracks, and spray foam is also useful in that capacity, especially around deck drains, etc., so long as there is solid backing. Note that construction paper and aluminum are not to be used to patch lost-deck forms.

2-2.2 Depths of Structural Sections

Check deck slab thickness, including the effective depth(s) and coverage of reinforcing steel, to ensure structural adequacy and conformance. This is usually done by measuring from a string line pulled between the screed rails or bulkheads prior to the finishing machine adjustment. Additionally, take a measurement from the strike-off or rollers of the finishing machine during the adjustment of the machine. During the pour, check the depths again by stabbing the plastic concrete following strike-off. See Figure 2.2-1 for a visual of a good tool for checking depth—a snap tie with the correct deck thicknesses marked.

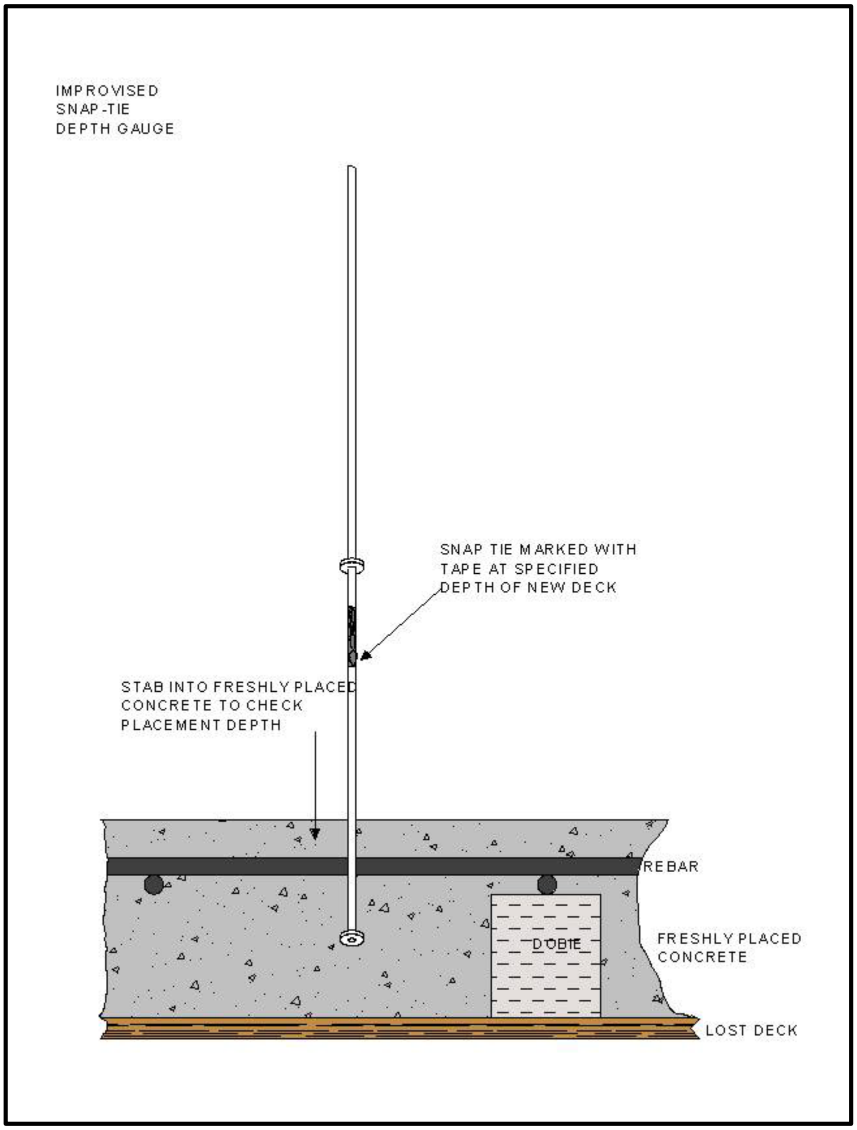


Figure 2.2-1. Diagram of How to Use an Improvised Snap Tie Depth Gauge.

Effective depth and clearance of reinforcement is discussed in Chapter 3, *Reinforcing Steel*.

2-2.3 Hinges, Construction Joints, Paving Notches, and Approach Slabs

When using a finishing machine, set forms or bulkheads for hinges and expansion and construction joints approximately 0.25 in low to clear the rollers and to make the grade at the joint. After final floating, attach a filler strip or edger board to the form for dressing and edging the joint, or saw cut the edge later. After the finishing machine passes, check the section of deck leading up to the joint at several locations with a straightedge held longitudinally to the bridge (See Figure 2.2-2). This allows the concrete finishers to blend in the joint and match the deck.

Figure 2.2-2. Finisher Checking the Freshly Placed Deck Concrete Near the Expansion Joint Blockout.

On multi-frame bridges connected by a hinge, it is important to adjust grades so that the final surfaces match on either side of the hinge. See Memo to Designers *11-34*, *Hinge Curl* for details. After the first deck is poured, profile and monitor it. Using the information from the first deck, adjust the grades of the second deck to match the first. Don't forget to include settlement in the second deck grades when trying to match the first.

After the deck concrete is placed, construct the top section of the abutment backwall, formed between the expansion joint and paving notch. Use the deck surface to establish the finished plane for this section.

Check proposed approach slab grades (as well as the entire bridge) with the road plans when reviewing the 4-scale drawings. After the bridge deck is poured, it should be profiled so that adjustments can be made in the approach slab grades if necessary. Typically, profiling the last 100 ft of the bridge deck is sufficient to make any adjustments between the as-built deck profile, the new approach slab, and the new roadway profile. Consult with District personnel so that both parties are aware of any proposed grade changes.

2-2.4 Overhangs

The importance of stability of the deck overhang forming systems for aesthetic reasons and deck grade control was noted earlier. To avoid repetition, their inspection is included in the following:

1. Chapter 4, *Grade Control, Screeds and Bulkheads*.
2. Inspection Check List for bridge forming and support systems in *Field Construction Practices Manual.*

2-2.5 Miscellaneous Items–Drains, Conduit, etc.

All drains, conduit, manholes, etc. should be shown and identified on the 4-scale layout and grade sheet for each structure. Attach road plans and standard plans showing pertinent drainage, electrical details, and sign details to the bridge plans for reference.

Miscellaneous items must be checked for proper location and be adequately secured to prevent movement during concrete placement and finishing operations. Set drains low enough to be in accordance with the plans. Set the plane of the grate parallel to the deck surface with the inlet properly sealed to prevent entrance of concrete and other foreign material.

2-2.6 Expansion Joints[7]

Saw cut joints to be sealed with type A and B seals at locations shown on the contract plans and to the dimensions determined in accordance with *Bridge Construction Records and Procedures Manual,* BCM 135-2.0, *Bridge Deck Expansion Joints and Joint Seals*.

Figure 2.2-3. Threaded Spacer Rods Used to Hold the Correct Width.

[7] 2006 SS, 51-2.02. *Sealed Joints*.

Figure 2.2-4. Joint Seal Assembly Installation.

Place joint seal assemblies in block-outs between the deck and approach slab or in hinge sections. Concrete is then deposited around the assembly. Typically threaded spacer rods hold the correct width of the seal assembly opening as concrete is placed around the joint seal assembly (as shown in figure 2.2-3). The Contractor should submit shop drawings for joint seal assemblies early for acceptance so that the reinforcing steel can be checked for proper clearance at these locations. Figure 2.2-4 shows an example of a joint seal assembly being installed.

Set these assemblies to exact bridge deck grade and carefully check grade for their entire length. The assembly is sometimes warped or bent during fabrication by welding or galvanizing, in which case they should be straightened by reworking. Give careful inspection consideration to skewed joints so the assembly fits properly at the barrier rail. See *Bridge Construction Records and Procedures Manual,* BCM 135-2.0, *Bridge Deck Expansion Joints and Joint Seals,* for more discussion on joint seal assemblies.

Prior to joint seal installation, conduct grinding to avoid any damage to the joint seal or assembly. The *Standard Specifications* do not require deck grinding to be completed prior to the installation of type A or B joint seals, as it does for joint seal assemblies. Unless deck grinding is performed first, the correct depth of installation remains uncertain. To achieve a smooth deck before installing the joint seal assembly, place asphalt or concrete (rat slab) over a sand bed in the joint seal assembly block-outs prior to deck grinding. The Contractor is responsible for any damage to the joint seal assembly and is responsible for constructing the completed roadway surface true to the required grade and cross section, including smoothness across the joint seal or assembly[8].

[8] 2010 SS, 51-1.03F(5), *Finishing Roadway Surfaces*.