Chapter 4: Design Considerations

Table of Contents

4-1 Introduction

This chapter covers design considerations which must be addressed during design and review of shop drawings. Subsequent chapters cover specific design methods and procedures.

Shop drawings must not be authorized if the applicable design considerations have not been addressed properly in the design.

4-2 Deflection and Camber

4-2.01 Maximum Allowable Deflection

The maximum allowable beam deflection is limited to:

$$\Delta_{\max} \leq \frac{L}{240} \tag{4-2.01-1}$$

where $\Delta_{\max}$ = Max allowable beam deflection

L = Span length of falsework beam

The deflection is calculated using the weight of all the concrete in the whole superstructure cross section, as though the entire superstructure were placed in a single concrete pour; the weight of the falsework is not included in the calculation. See *Contract Specifications*, Section 48-2.02B(3), *Stresses, Loadings, and Deflections*. This limiting value is included in the specifications to ensure a certain degree of rigidity in the falsework and thereby minimize distortion of the forms as concrete is placed.

4-2.02 Actual Deflection

The actual deflection is the deflection that occurs as the falsework beam is loaded. Calculating actual deflection is the Engineer's responsibility, since it is used in determining the amount of falsework camber required.

When calculating the actual deflection, include the weight of:

- Concrete, reinforcement, and forms (160 pounds per cubic foot (pcf)).
- The supporting beam (pounds per linear foot (plf)).

Consideration must be given to such factors as the sequence of construction and the depth of the superstructure when two or more concrete pours are involved.

The specifications do not include a limiting value for live load deflection, as they are of a transient nature. However, when a bridge deck finishing machine is supported at the outer edge of a cantilevered deck overhang, particular care must be taken to prevent excessive deflection of the deck overhang support system. Unless special precautions are taken, the concentrated load, due to the weight of the finishing machine, may cause the deck overhang to deflect appreciably with respect to the remainder of the deck surface. This will decrease bridge deck thickness and reduce reinforcing steel cover, both of which are detrimental to the completed structure.

The applicable specification is the general requirement that falsework must be designed and constructed to produce, in the finished structure, the lines and grades shown on the plans. See *Contract Specifications*, Section 48-2.01A, *Temporary Structures – Falsework – Summary*. To ensure compliance with this general requirement, add the "deflection due to the weight of a deck finishing machine" to the "deflection due to the weight of the concrete". The sum of these two deflections should not be too large as to adversely affect the character of the finished work. This will require engineering judgment. In summary, the important point is that the weight of the finishing machine be considered, and the total deflection limited to a realistic value.

4-2.03 Negative Deflection

Depending on the concrete placing sequence, negative (upward) deflection may occur where falsework beams are continuous over a long span and a relatively short adjacent span. This condition (negative deflection at the end support) is an indication of system instability and must be considered in the falsework design. If beam uplift cannot be prevented by loading the short span first, the end of the beam must be restrained, or the span lengths must be revised. Designs where theoretical beam uplift will occur under any loading condition must not be authorized.

When falsework stringers are considerably longer than the actual falsework span, the stringer cantilever extending beyond the point of support will deflect upward as the main span is loaded. The design must include provisions to accommodate this upward deflection. The usual method is to use a sleeper (filler strip) on the main span only, which allows free movement of the stringer cantilever. The sleeper should end at the center line of the falsework top cap and should not extend into the cantilever section of the stringer. The sleeper must be thick enough to offset the theoretical uplift on the cantilever, see Figure 4-1, *Sleeper on the Falsework Stringer*.

Note: No sleeper on beam tails.

Figure 4-1. Sleeper on the Falsework Stringer

Sometimes the Contractor may use the steel beam cantilever beyond the support, with wood beams wedged tight between its flanges, to close the gap at abutment and bent faces. This may be acceptable for a closure distance up to 4 feet. This detail, when applied to longer distances, can cause depression in the wet soffit concrete due to stringer tail movement when concrete is placed in the main span. This should be discouraged.

4-2.04 Camber

The term "camber" is used to describe an adjustment to the profile of a load supporting beam or stringer so the completed structure will have the lines and grades shown on the plans. In theory, the camber adjustment consists of the sum of the following factors:

1. Anticipated total deflection of the falsework beam (stringer) under its own weight and the actual load imposed
2. Difference between the falsework beam profile and profile grade, also called vertical curve compensation
3. Difference between the falsework beam profile and ultimate superstructure deflection curve (bridge camber)
4. Difference between the falsework beam profile and any permanent or residual camber to remain in the structure for its useful service life

In structures with parabolic soffits, an additional adjustment will likely be required to account for the difference between beam profile and soffit curvature. On parabolic soffits the vertical curve component is sometimes included with the soffit profile (4-scale) grades.

When falsework beams are relatively short, the theoretical adjustment due to vertical curve compensation, bridge camber, and desired permanent or residual camber will be small and may be neglected. As falsework spans increase, these factors become increasingly significant and must be considered along with beam deflection.

More than any other single factor, the satisfactory appearance of a completed structure will depend on the accuracy of the camber used in the falsework construction. Good judgment will be required, particularly in determining the amount of camber to be used to compensate for anticipated dead load falsework deflection, take up, and settlement.

In general, the deck weight of a conventionally reinforced box girder bridge should be omitted when calculating camber, since additional stringer deflection as the deck is placed usually is insignificant. In the case of cast-in-place prestressed construction, falsework span length may be an important consideration. In such structures, judgment will be required as to the relative stiffness of the girder stems, and whether they will resist additional deflection and by how much, as the deck is placed. Experience has shown that including 10-20% of the deck weight for deflection is a reasonable estimate for typical prestressed box girder bridges.

The Engineer furnishes the amount of camber to use in constructing falsework; see *Contract Specifications,* Section 48-2.03C, *Falsework – Erection*.

4-2.04A Camber Strips

When to require camber strips is a matter of engineering judgment. Generally, camber strips are not necessary unless the total camber adjustment exceeds approximately 1/4-inch for stringers supporting the exterior girders, edge of the soffit, or deck overhang, and approximately 1/2-inch for beams at interior locations. The Engineer orders the Contractor to furnish camber strips. See *Contract Specifications*, Section 48-2.03C, *Falsework – Erection*.

To warrant proper design and installation, camber strips must conform to the following criteria:

1. 900 psi maximum allowable compressive stress for perpendicular-to-grain loading (increased from values found in NDS)
2. 1.5-inch minimum width
3. 1/8-inch maximum crushing
4. Must be centered along the longitudinal centerline of the falsework beam
5. Structure cross slope, allowable wood crushing, and joist deflection must be considered when determining the height of the camber strip.

6. The minimum height of the camber strip must be such that the joists will not come into contact with any part of the falsework beam under any loading condition.
7. Must not extend onto the unloaded portion of a trailing beam cantilever
8. If the amount of camber is large, as in the case where a parabolic curved bridge soffit is supported by a long falsework beam, the camber strips should be braced or built up with wide material to avoid lateral instability. The use of laterally unsupported tall, narrow camber strips is not permitted.
9. A sleeper is required when the stringer does not follow bridge cross slope and camber strip does not include allowance for cross slope, see Figure 4-2, *Camber Strip and Sleeper Requirements.*

Because camber strips are an incidental part of the system, their installation seldom receives more than cursory attention. Casual treatment of camber strip installation can result in an unforeseen and undesirable loading of the falsework beam. For example, a camber strip placed at a distance away from the centerline of a steel beam may induce torsional stresses that were not considered in the design. Undesirable torsional stresses may be induced in beams supporting falsework for structures having steep cross slopes, even if the camber strip is properly placed along the beam centerline.

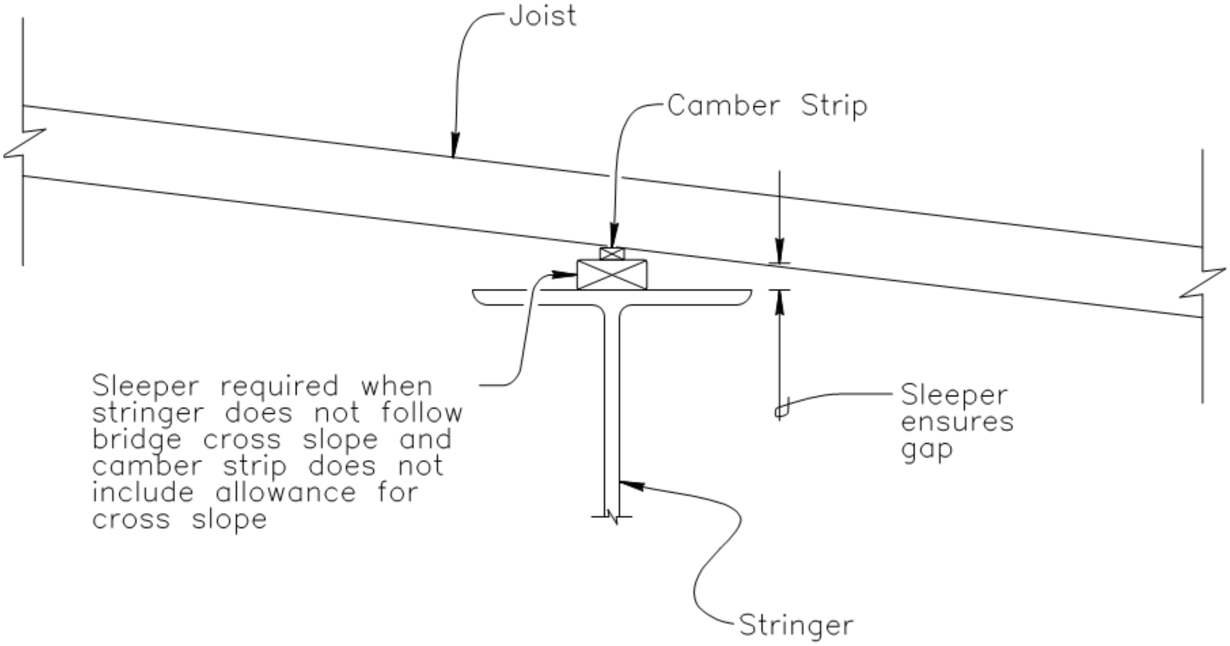


Figure 4-2. Camber Strip and Sleeper Requirements

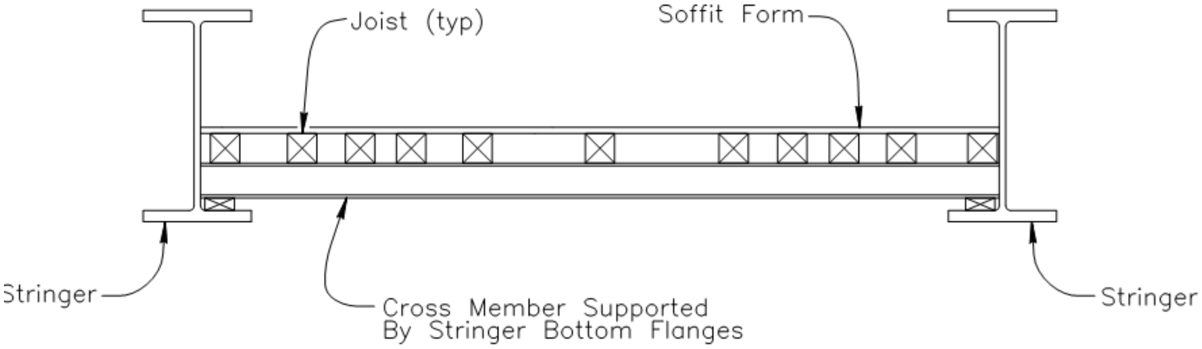
4-2.05 Horizontal Deflection

Although the specifications do not include a limiting value for horizontal deflection, such deflection will be negligible in any falsework system where horizontal forces are resisted by bracing. Horizontal deflection need not be considered in any case where the horizontal design load is resisted by a properly designed bracing system. This includes external bracing systems where the use of external bracing is necessary to prevent overturning.

Horizontal deflection will be a consideration when the horizontal design load is resisted by bending in a falsework member. This situation occurs when falsework is supported by pile bents. For pile bents, it is necessary to combine bending and vertical load stresses to obtain the actual stress.

The procedure for evaluating the adequacy of falsework pile bents is discussed in Section 8-6, *Pile Foundations*.

Horizontal deflection may be an issue with falsework where the stringers are loaded on the bottom flange and not directly over the web. Loading stringers this way may cause the top flange to move horizontally. See Figure 4-3, *Bottom Flange Loading*.



Note:

Superstructure and other falsework omitted for clarity

Figure 4-3. Bottom Flange Loading

4-3 Beam Continuity

Because of the sequential, and sometimes unpredictable way falsework loads are applied, beam continuity is an uncertain design condition. To accommodate this uncertainty, assume the continuous beam condition when continuity will act to increase loads or stresses, but not otherwise.

For example, the simple span condition will be assumed when calculating positive bending moments in joists, stringers, and similar continuous members; however, full continuity will be assumed when calculating negative bending moments in these same members. Assume full continuity when calculating the beam reaction on interior supports under continuous falsework members but assume the simple span condition when calculating the reaction at the end support.

In a framed bent, continuity must be considered in any case where stringer loads are applied within the cap span rather than directly over the supporting post to ensure that allowable post loads are not exceeded.

Continuous caps are often supported by two or more towers in a heavy-duty shoring system. If leg loads are unequal, the resulting differential leg shortening will cause a redistribution of beam reactions and a corresponding change in the magnitude and location of maximum cap bending stress.

When beams are continuous over two or more spans, beam uplift can occur in adjacent unloaded spans when concrete is placed in one span. Refer to discussion in Section 4-2.01A, *Negative Deflection*.

The Engineer will be expected to recognize these and other cases where the effect of beam continuity must be investigated to prevent the overstressing of any falsework member or instability in the system.

4-4 Cap Beam Center Loading Strips

4-4.01 Introduction

Timber center loading strips or shims are sometimes used as a method for transferring the load from stringers to cap beams. Center loading strips aid in transferring the vertical reaction load from stringer to cap concentrically. This prevents the stringer bottom flange from bearing on the flange edges of the cap. Otherwise the stringer can induce torsional rotation in the cap if the stringer bears on points other than the center of the cap. It is critical that center loading strips are symmetrically located about a vertical line that passes through the webs of both the stringer and the cap. This ensures the transfer of the force reactions from stringer to the cap through the web of cap thereby preventing any unintended moment on the cap. See Figure 4-4. *Center Loading Strip Details*.

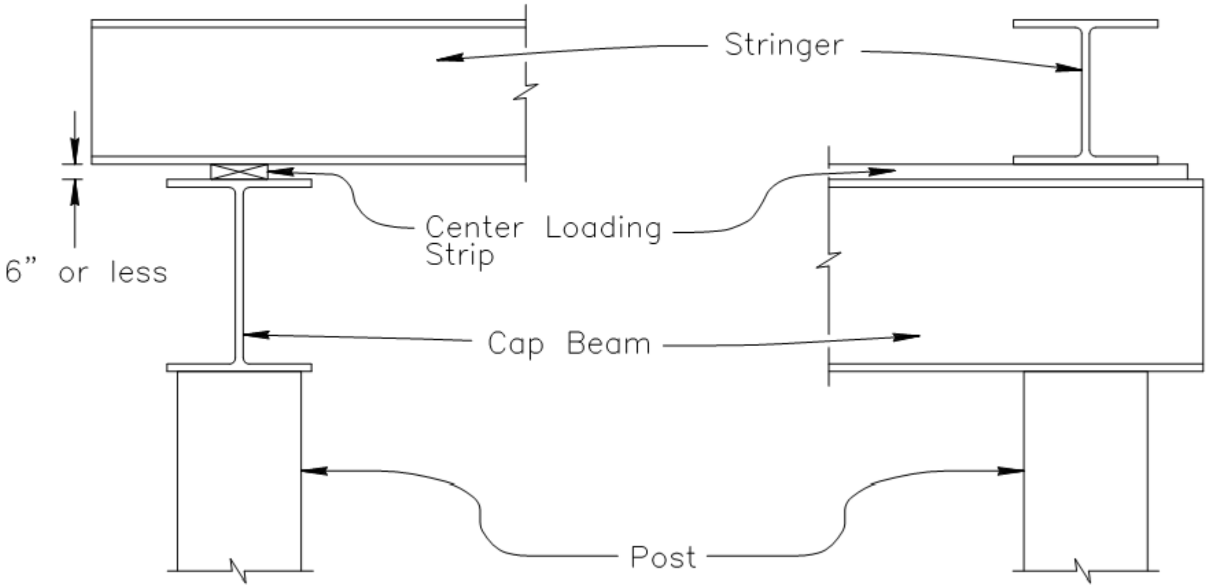


Figure 4-4. Center Loading Strip Details

4-4.02 Design Criteria

The maximum thickness of loading strips or shims must not exceed:

- 6 inches
- This limit also applies to multiple built-up strips or shims. This maximum thickness limitation eliminates excessive build-up between the cap and the stringer beam that could lead to stability problems

The allowable compressive stress for perpendicular-to-grain loading for center loading strips is:

- 900 psi for single strip or shim up to 6 inches thick.
- Comply with National Design Specifications (NDS) for multiple strips or shims with a combined thickness up to 6 inches thick.

4-5 Construction Sequence

4-5.01 Introduction

Unless a concrete placing sequence is shown on the bridge plans, the shop drawings must include a placing diagram showing the proposed placing sequence and the location of all construction joints. If a placing schedule or sequence is shown on the plans, no deviation is permitted, and the falsework must be designed and constructed to accommodate the planned placing sequence.

4-5.02 Transverse Construction Joint

The location of transverse construction joints in the bridge superstructure is an important falsework design consideration. If a construction joint is located near the mid-point of a falsework beam, the initial concrete pour on one side of the joint will deflect the beam as the concrete dead load is applied. Later, as concrete is placed on the opposite side of the joint, additional beam deflection will occur. The additional beam deflection leaves the first concrete placed to be unsupported, and this can result in unanticipated detrimental stresses and even cracking in the permanent structure. To avoid this condition, transverse construction joints in the bridge superstructure should be designed and constructed in such a manner that subsequent pours will not produce additional stresses in the concrete already in place. In many cases the exact location of a construction joint is not critical, and the joint can be moved a few feet in either direction to accommodate the falsework design. The important point, however, is that the joint location be considered in the falsework design with respect to falsework beam span, thus avoiding a problem during construction.

4-6 T-Beam Bridges

When relatively long falsework spans are used to support T-beam structures, the added weight of the deck concrete, which often exceeds the weight of the stem, loads the stem and the falsework as the deck concrete is placed. This can produce stresses of considerable magnitude in the concrete and reinforcing steel in the girder stem.

To prevent overstressing of concrete and reinforcing steel in the girder stems of T-beam girder bridges, the *Contract Specifications*, Section 48-2.02B(1), *General*, limit the length of falsework spans to:

$$\mathbf{L = 8.5T + 14} \qquad (4\text{-}6\text{-}1)$$

where **L** = Length of falsework span (ft)

T = Depth of T-beam girder measured from top of deck to bottom of girder (ft)

Occasionally contractors request to use a longer falsework span than allowed by the specifications. It is acceptable to exceed the specified span length provided the criteria in Section 5-8, *Longer T-Beam Falsework Spans,* are satisfied.

4-7 Friction

4-7.01 Introduction

Friction used as a means of resisting opposing horizontal forces is a very intangible factor. The use of friction for this purpose should be considered with caution. The coefficient of friction should be assumed as not being greater than 0.30 maximum for all contact surfaces. The only exception to this friction factor is for concrete anchor blocks, see Section 5-5.13A, *Cable Anchored to Concrete Blocks*.

In general, friction may be considered as resisting the tendency of one member to slide over or across another member, provided frictional resistance is actually developed under the loading condition being investigated.

Do not consider frictional resistance in any case where the dead load is not applied uniformly through all stages of construction, or where continuity would reduce the load acting on a support under a non-uniform loading condition.

Do not consider frictional resistance as contributing to the lateral stability of beams or stringers. If flange support is required, the method of support must be positive and independent of any theoretical frictional resistance.

Do not consider friction as contributing to the resisting capacity of any connecting device unless the device is specifically designed and marketed as a friction-type connector, except as otherwise provided in the Section 7-3.06, *C-Clamps*.

4-8 Prestressing Forces

When cast-in-place prestressed structures are stressed, the initial stressing produces an upward deflection in the positive moment area, and the resulting redistribution of vertical forces transfers the superstructure dead load from the falsework to the adjacent abutments and columns.

The *Contract Specifications,* Section 48-2.02B(2), *Design Criteria – Loads,* require that the falsework must support any increase or readjustment of loads caused by prestressing forces.

An example of dead load redistribution due to longitudinal prestressing is stage construction of continuous bridges with hinges. For these bridges, prestressing will reduce the dead load on the falsework near the center of the suspended span and increase the load on the falsework at the hinge. The forces involved in the dead load redistribution are of considerable magnitude, since up to 3/8 of the total suspended span dead load may be transferred to the falsework at the hinge, assuming the span acts as a fixed-pinned beam. The load due to dead load transfer is shown in the contract drawings and includes the secondary prestress forces. In addition, the dead load of the falsework, calculated in the usual manner, along with the falsework live loads over the deck surface, assuming a fixed-pin beam configuration, will need to be added to the hinge loads provided on the contract plans.

If the dead load hinge reaction (the load applied to the cantilever span by the supported span) is not shown on the contract plans, it may be obtained from the designer.

The effect of transverse prestressing is a falsework design consideration. If the structure is designed to include transverse prestressing of decks or caps, the project plans will include the stressing sequence, and the falsework must be designed to accommodate the sequence outlined on the plans.

4-9 Long-Term Superstructure Deflection

Depending on factors, such as the length of time the falsework is to remain in place and the method and sequence of removal, long term deflection of the bridge superstructure occurring after prestressing may be a design consideration.

Long term superstructure deflection will begin as soon as the structure is stressed. As deflection occurs, a portion of the dead load initially transferred to the falsework at the hinge will be carried back to the falsework near the center of the span. The amount of dead load carried back is a function of time and is not easy to predict. However, this should not present a problem in most cases because the load carried back cannot exceed the load originally resisted by the falsework.

If falsework is removed in stages, field engineers should be aware that part of the redistributed load will be carried back with time, and that components of the falsework system remaining in place near the center of the span will be subjected to a gradually increasing load as superstructure deflection takes place. Dead load carried back may be an important consideration when evaluating the adequacy of a given falsework removal sequence. See also Section 9-5.03, *Stage Construction,* for removal sequence considerations.

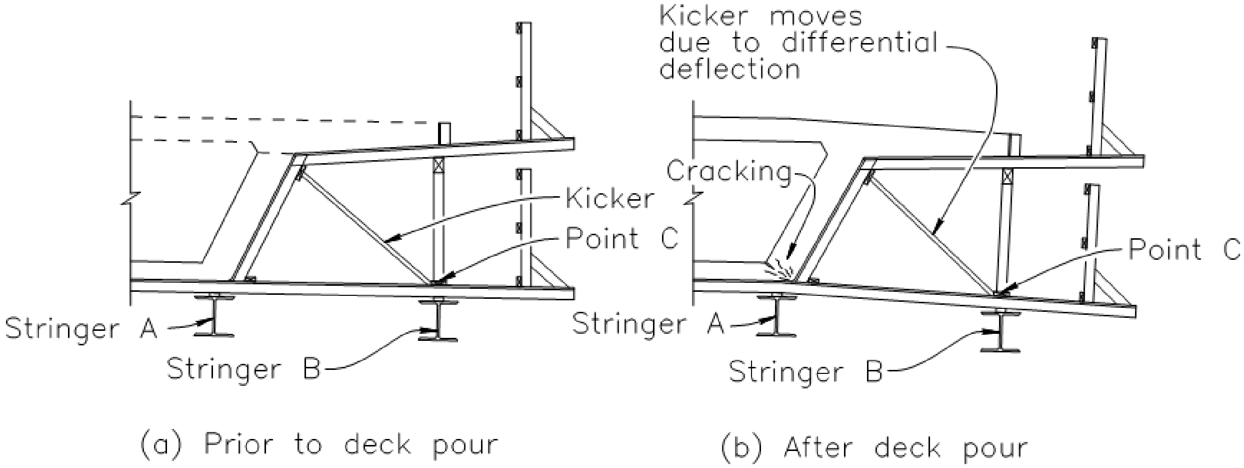
4-10 Falsework at Deck Overhangs

4-10.01 Introduction

For box girder structures with cantilevered deck overhangs, the normal 2-stage construction sequence results in differential loading of the exterior and first interior falsework beams. The differential loading condition is exacerbated if the exterior girder is also sloping outward at the top, as is usually the case. Depending on the beam size and location, differential loading may result in differential beam deflection, causing the exterior girder stem to rotate. Girder rotation may occur during the girder stem pour or during the deck pour, or during both pours.

4-10.02 Stem and Soffit Pour

Referring to Figure 4-5(a), *Deck Pour Differential Deflection – Prior to Deck Pour*, during a girder stem pour, stringer A may deflect more than stringer B, causing a downward movement of stringer A relative to point C. This downward movement of stringer A causes the girder-stem form to rotate inward. Inward rotation will affect alignment and grade at the top of the girder stem and will cause the rebar in the stem and soffit corner to move during the pour. If the inward rotation is small, minor adjustments can be made to the grades before the deck pour and the movement of the rebar will be negligible. If the inward rotation is large, it may not be possible to make the grade adjustments before the deck pour and the rebar in the stem and soffit corner may move out of place and create separation during the pour. The effects of differential stringer deflection during the girder stem pour must be investigated as a precautionary measure to determine whether any adverse consequences will occur. If the soffit is placed separate from the stem, it may be necessary to realign the stem forms before placing the stem concrete.



(a) Prior to deck pour (b) After deck pour

Figure 4-5. Deck Pour Differential Deflection

4-10.03 Deck Pour

Referring to Figure 4-5, *Deck Pour Differential Deflection,* a situation may develop during the deck pour where the weight of the deck overhang may cause stringer B to deflect more than stringer A. This differential deflection causes a downward movement at point C relative to stringer A, which pulls the kicker away from the girder stem form panel and leaves the sloping exterior girder unsupported causing it to rotate outward. This will induce torsional stresses in the concrete and reinforcing steel at the girder base. This outward rotational moment is exacerbated by the weight of the deck concrete on the inside of the exterior girder.

The load applied to the exterior and adjacent interior falsework beams, during the deck pour, should be investigated in all cases where the depth of a box girder structure, having sloped exterior girders, exceeds 5 feet. When the applied loads result in differential beam deflection of sufficient magnitude to cause the exterior girder support system to become dysfunctional, the falsework design must include means to resist girder rotation. The method by which this is accomplished must be shown on the shop drawings, such as tiebacks to the base of the adjacent interior girder.

4-11 Concrete Deck on Steel Girders

4-11.01 New Steel Girder Bridges

The *Contract Specifications*, Section 55-1.03B, *Steel Structures – Falsework,* include special requirements for falsework supporting the concrete deck on steel girder bridges. These requirements are included to control the manner falsework loads are applied to the steel girder, and thus prevent undesirable distortion of the permanent structure. See Figure 4-6, *Steel Girder Falsework*.

Horizontal loads applied to the girder flanges by the falsework will produce a torsional moment in the girder. To prevent possible overstressing of the permanent diaphragm connections, the falsework design must include temporary struts and/or ties to resist the full torsional moment and to prevent appreciable relative vertical movement between the edge of deck form and the adjacent steel girder.

The falsework must be designed and constructed to comply with *Contract Specifications,* Section 55-1.03B, *Steel Structures – Falsework, as follows*:

1. Any loads applied to the girder web must be applied within 6-inches of a flange or stiffener.
2. Temporary struts must be provided as necessary to resist lateral loads.
3. The applied loads must be distributed to prevent local distortion of the web.

Contract Specifications, Section 55-1.02E(7)(a), *Steel Structures – Fabrication – Welding – General,* do not allow welding or tack welding of brackets, clips, shipping devices, or any other material not described to any part of the girders unless it is shown on the girder shop drawings.

Figure 4-6, *Steel Girder Falsework*, shows conventional falsework for the interior deck forms, however, it is common to use stay in place steel deck forms for the interior deck.

The top flange of the steel girders must be surveyed after the girders are erected, but before any load is placed on them. This step is necessary to verify that the theoretical girder dead load camber shown on the bridge contract plans was achieved. Any deviation in the camber must be accounted for by adjusting the thickness of the fillet between the top of the girder flange and the bottom of the deck.

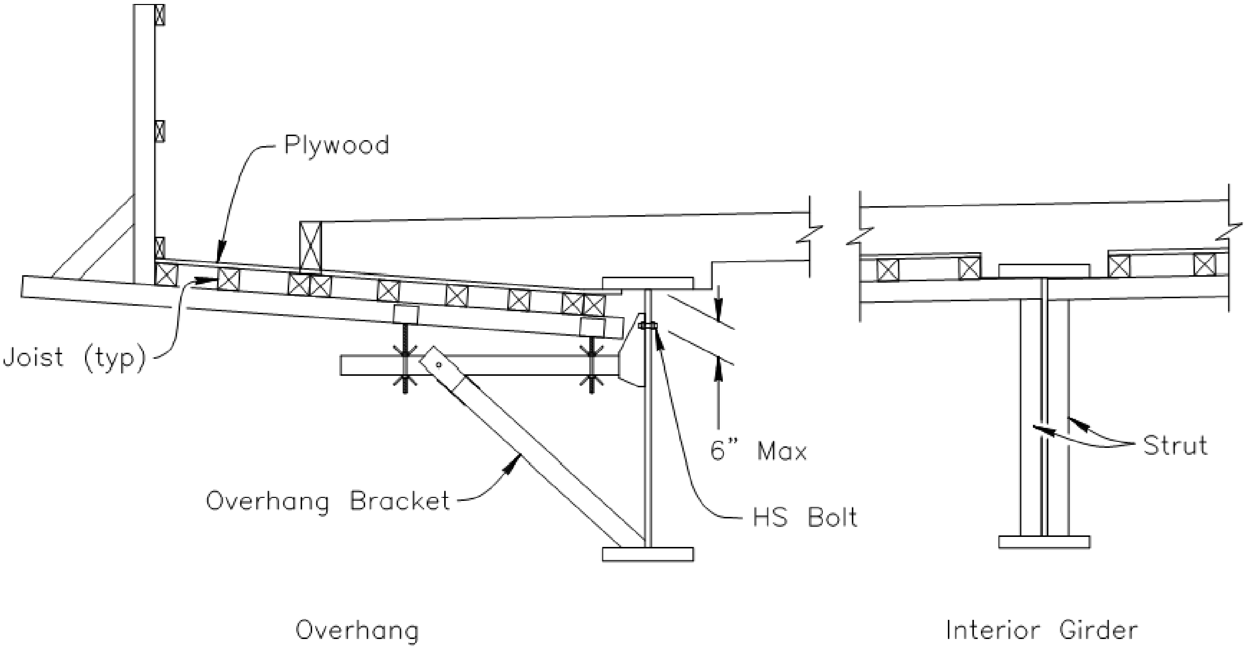


Figure 4-6. Steel Girder Falsework

4-11.02 Steel Girder Widenings

In addition to the requirements stated in the previous section, special attention must be given to deck falsework on widenings. A steel girder bridge widening must be constructed as an independent "bridge" and then tied to the existing bridge with the closure pour.

Referring to Figure 4-7, *Steel Girder Widening Falsework*, the falsework on the new girder adjacent to the existing must be constructed independently of the existing bridge. Typically, it is constructed using overhang brackets to support the portion of the deck hanging over the new girder next to the closure pour.

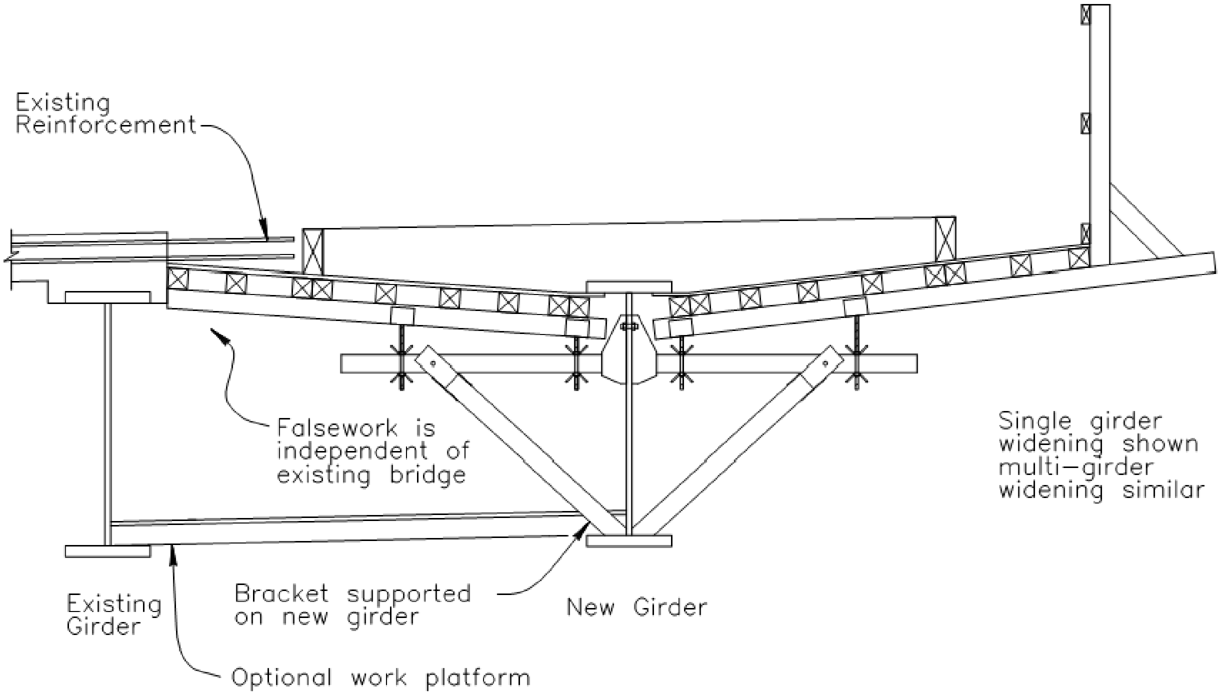


Figure 4-7. Steel Girder Widening Falsework

Referring to Figure 4-8, *Incorrect Steel Girder Widening Falsework*, the portion of the new deck, hanging over the new girder towards the closure pour, must not be supported by the existing girder. The existing girder is in its final position, but the new girder will deflect downward during the deck pour. The deflection can be up to several inches depending upon the span length and girder stiffness.

If this portion of the deck is supported on the existing girder, the deck form between the new and existing girder will continue to move as the deck pour proceeds along the new girder and the new girder continues to deflect. This will also result in the following:

1. Point A: The slope on the new deck will change
2. Point B: Rebar in the concrete placed earlier in the pour will keep moving resulting in debonding, e.g. when the pour is at mid-span, the forms and rebar at 1/4-span are still moving due to the girder deflection.
3. Point C: The concrete may debond from the steel girder.
4. Point D: The outer screw jack will deflect down the same amount as the inner screw jack, but the joist will move less at the outer screw jack, causing the joist to only be supported at the inner screw jack and the post on the existing girder and hence the joist will be over loaded.

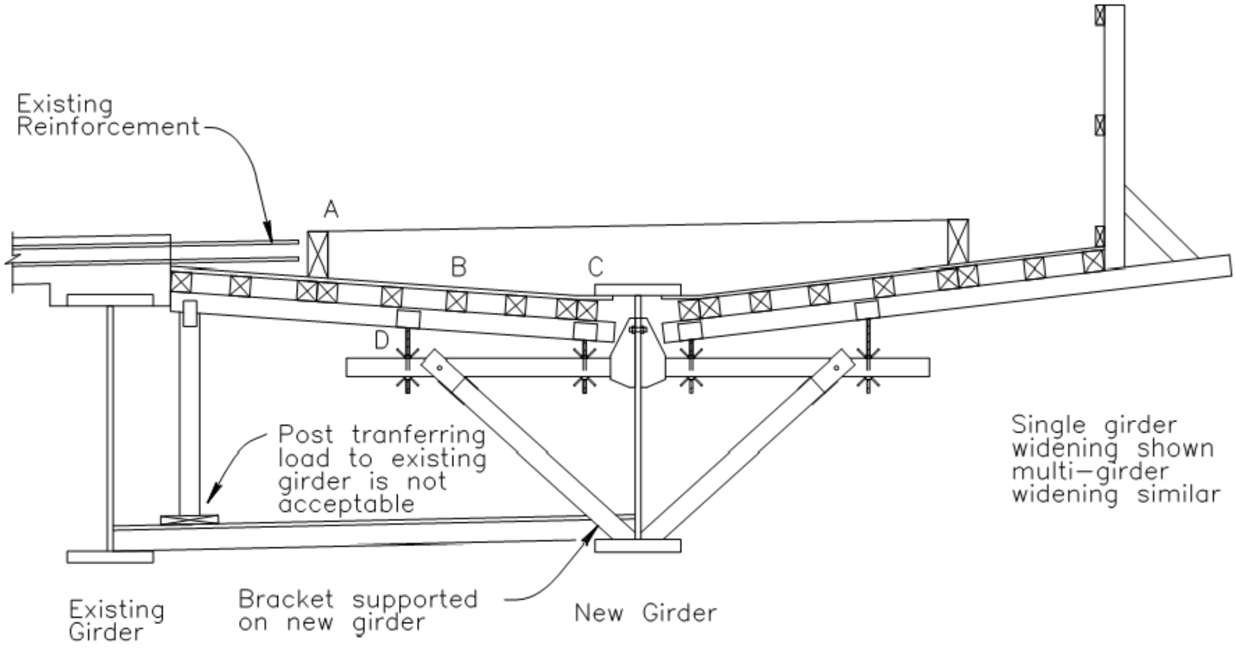


Figure 4-8. Incorrect Steel Girder Widening Falsework

The top of the steel girders must be surveyed after the girders are erected, but before any load is placed on them. This step is necessary to verify that the theoretical girder dead load camber shown on the bridge contract plans was achieved. Any deviation in the camber must be accounted for by adjusting the thickness of the fillet between the top of the girder flange and the bottom of the deck.

4-12 Falsework Over or Adjacent to Roadways or Railroads

4-12.01 Introduction

The *Contract Specifications*, Section 48-2.02B(4), *Falsework – Design Criteria – Special Locations,* include special requirements, which apply only to falsework over or adjacent to roadways and railroads that are open to traffic. These requirements are included to ensure higher standards of design and construction at locations where public safety is involved.

Falsework posts are adjacent to roadways or railroads if:

- The post supports members that cross over roadways or railroads.
- The post is located such that the horizontal distance from the traffic side of the falsework to the edge of pavement or to a point 10 feet from the centerline of

railroad track is less than the height of the falsework and forms. See Figure 4-9, *Falsework Adjacent to Roadways or Railroads*.

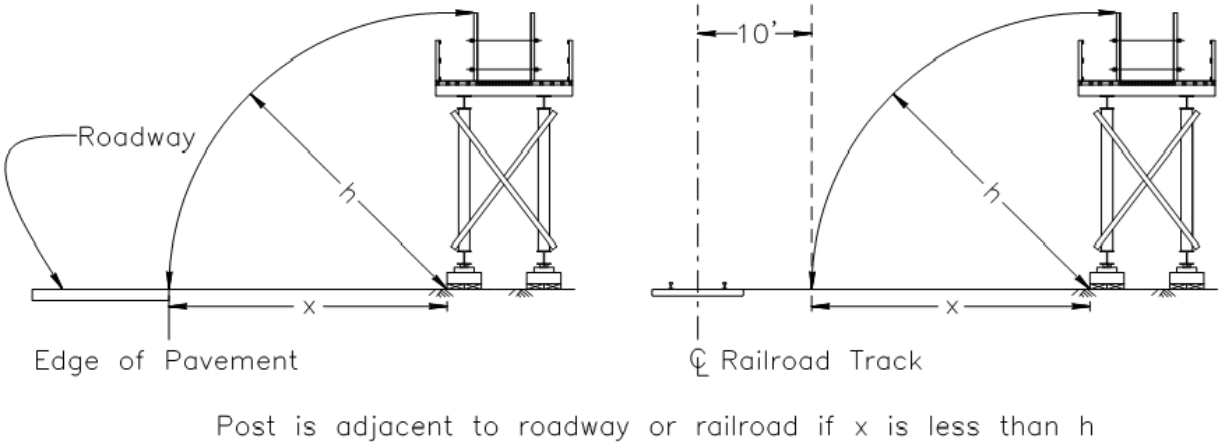


Figure 4-9. Falsework Adjacent to Roadways or Railroads

4-12.02 Falsework Openings

Whenever an operation will reduce clearances available to public traffic, the *Contract Specifications,* Section 7-1.04, *Public Safety,* require the Contractor to notify the Resident Engineer within a specified timeframe before the anticipated start of the operation. Moreover, the *Contract Specifications*, Section 12-4.02A(3)(b), *Traffic Control Systems – Submittals – Closure Schedules*, require the Contractor to submit a closure schedule request within a certain timeframe before the anticipated start of any job site activity that reduces horizontal or vertical clearance of traveled ways.

Referring to BCM C-6, *Required Documents to be Submitted During Construction*, the Structure Representative completes Form SC-4103, *Report of Falsework Clearance,* from the shop drawings. With this information, the Structure Representative then completes Form TR-0019, *Notice of Change in Clearance or Bridge Weight Rating,* or Form TR-0029, *Notice of Change in Clearance or Bridge Weight Rating,* as applicable. The form is submitted to the Resident Engineer as notification of the change. The Resident Engineer notifies the Transportation Permits Branch. After erection of the falsework, the Structure Representative verifies the clearance.

The minimum width and height of each opening to be provided through the falsework will be shown on the structure plans or in the special provisions.

The width of a vehicular opening is the distance between the temporary railings. The clear distance between falsework posts will be considerably greater than the width shown in the special provisions.

For a vehicular opening, no portion of the falsework may encroach into the clearance zone shown in Figure 4-10, *Clearance to Railing Members and Barriers*.

4-12.03 Horizontal Clearance

Horizontal clearances for permanent railing members and barriers must be at least those shown in Table 4-1, *Minimum Clear Area Width* (from the *Contract Specifications*, Section 48-2.02B(4)):

Table 4-1. Minimum Clear Area Width

Falsework Member	To permanent railing members and barriers
Footings (incl. pads and corbels)	0’-3”
Piles (incl. pile bents)	2’-6”
Other members	2’-6”

The clearance is measured from the portion of the railing or barrier closest to the falsework.

Horizontal clearances to temporary barrier systems must comply with *Contract Specifications,* Section 12-3.20, *Temporary Barrier Systems*.

Corbels are considered part of the footing or foundation. However, if corbels are used as build up, they are considered as other members.

4-12.04 Vertical Clearance

Calculating anticipated vertical clearance prior to falsework erection and measuring actual vertical clearance after erection is required to ensure Transportation Permits Branch is aware of impaired clearances. Transportation Permits Branch uses this information to issue transportation permits.

Example 1: *Clearances at Falsework Openings,* in Appendix D, *Example Problems,* illustrates proper methodology for calculating the anticipated minimum vertical clearance. The following specific factors should be considered:

1. Stringer bottom flange elevations over the roadway during all stages of construction. Measure the clearance to the lowest stringer over the roadway.
2. Verify if the point of minimum vertical clearance is over the roadway or behind the K-Rail during construction.
3. Whether or not falsework is skewed, etc.

Deflection of the falsework stringers under the dead load of the concrete will reduce the theoretical clearance, and this must be considered in the design.

Figure 4-11, *Points of Minimum Vertical Clearance,* shows that the point of minimum *final* vertical clearance of the bridge may not be the same as the point of minimum *temporary* vertical clearance for the falsework during construction.

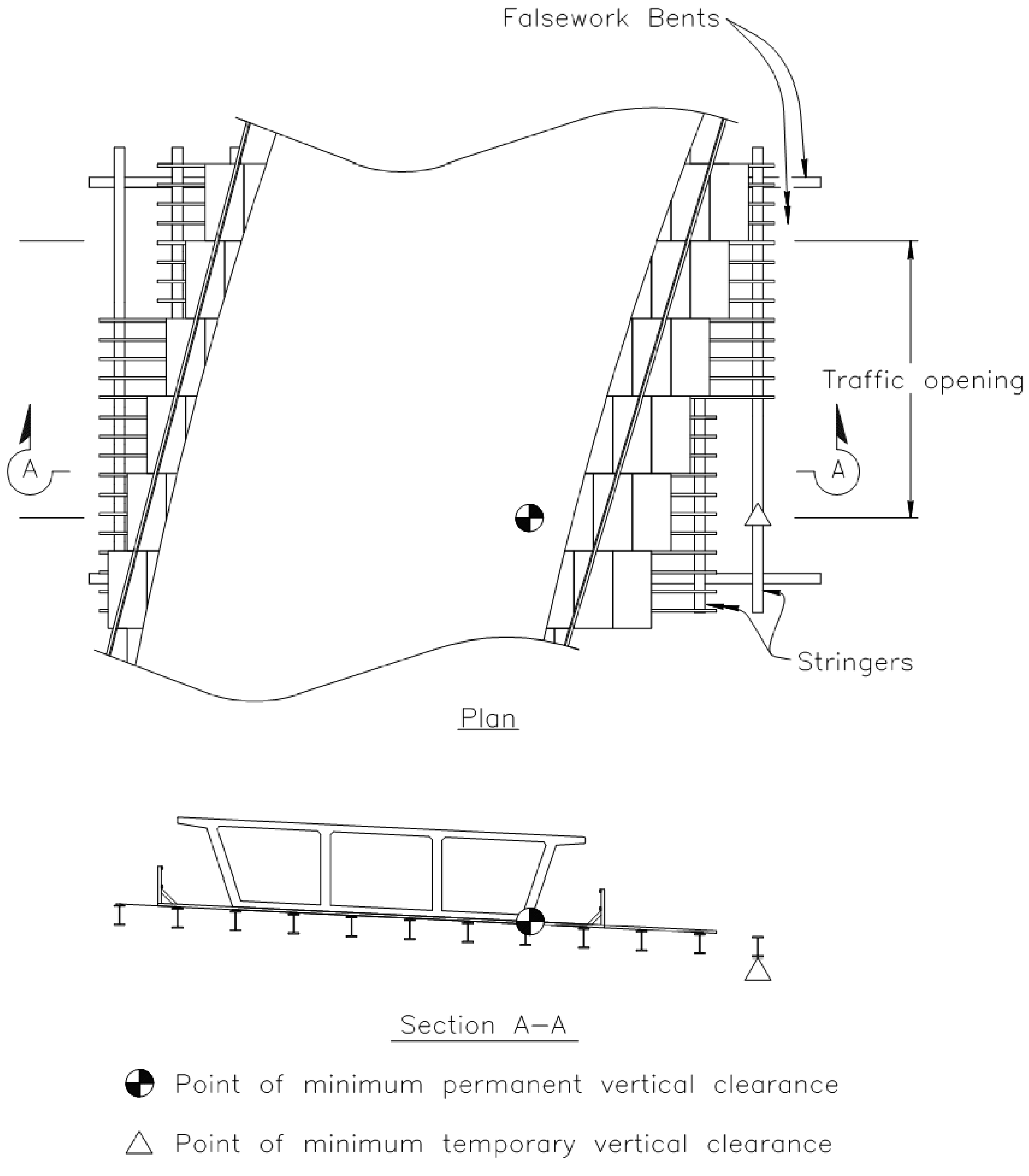


Figure 4-11. Points of Minimum Vertical Clearance

4-12.05 Requirements Over or Adjacent to Roadways or Railroads

4-12.05A Introduction

Refer to *Contract Specifications*, Section 48-2.02B(4), *Falsework – Design Criteria – Special Locations*. The special requirements discussed in this section apply to falsework over or adjacent to roadways and railroads and within the limits shown in Section 4-12.01, *Introduction*. Additional requirements that apply only to falsework over or adjacent to railroads are discussed in Section 4-12.06, *Additional Requirements Over or Adjacent to Railroads*.

Similar requirements also apply to falsework with bents perpendicular to or at an angle to roadways and railroads, which are not supporting members over the roadway or railroad, as explained in the following sections.

4-12.05B Post Material and Parameters

Falsework posts must be either:

- Steel with a minimum section modulus of 9.5 in^3 about each axis
- Timber with a minimum section modulus of 250 in^3 about each axis

When pipe frame or tubular steel components are used in falsework over or adjacent to a roadway or railroad, either as individual posts or as legs in a tower bent, the specified minimum section modulus for steel posts will apply to the post or tower leg, but not to the screw jack extension.

4-12.05C Impact Loads and Mechanical Connections

Each falsework post must be mechanically connected to its supporting footing or otherwise laterally restrained and comply with the following:

1. 2000 lb force applied at the base of the post is:
   a. Applied at the base of each post regardless of its size, spacing, or loading; however, it will be assumed as acting on only one post at a time.
   b. Applied in any direction except toward the roadway or railroad.
2. Lateral restraint must be effective as shown in Figure 4-12, *Application of 2000 Pound Load*.
3. For a bent in a highway median or in between railroad tracks, the restraint must be effective in all directions.

4 . For falsework with bents parallel or at an angle to roadways or railroads, this requirement applies to all posts within the limits shown in Section 4-12.01, *Introduction*, but not less than two posts for angled bents.

In the *Contract Specifications*, Section 48-2.02B(4), *Falsework – Design Criteria – Special Locations*, the term support footing means the element of the falsework system that is set on the ground.

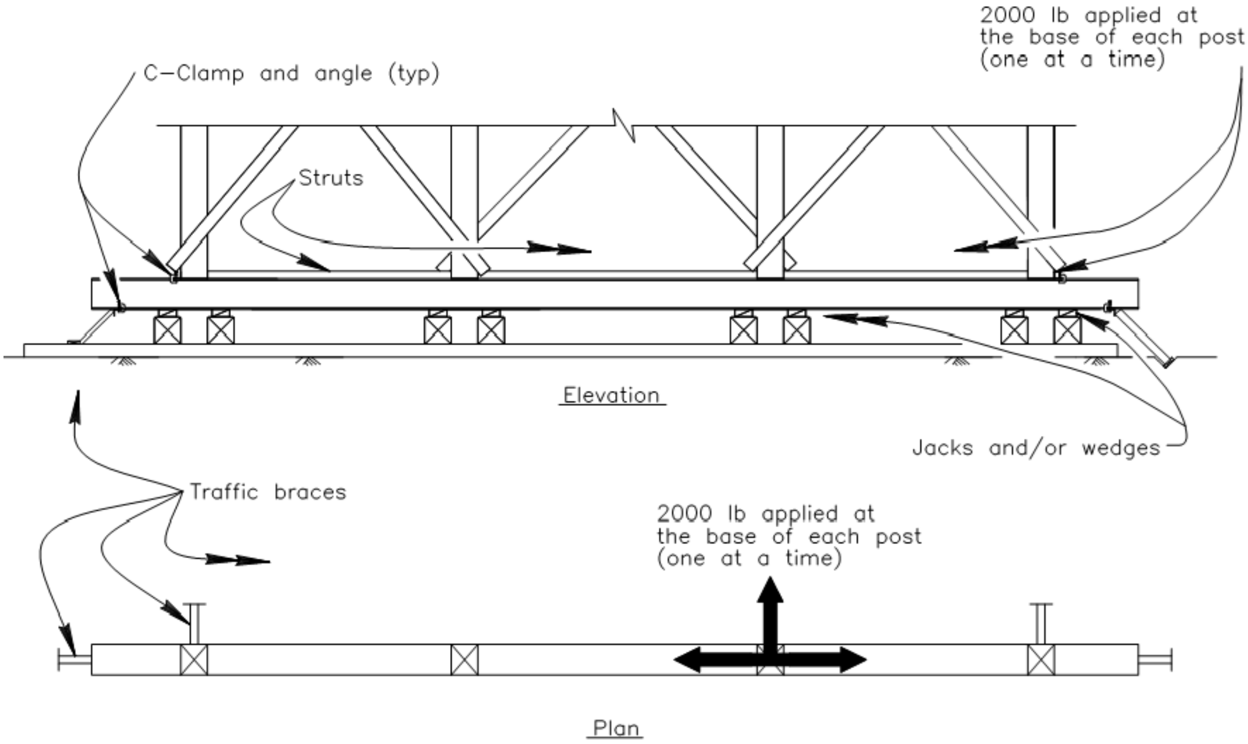


Figure 4-12. Application of 2000 Pound Load

Many contractors prefer to adjust falsework to grade by wedging or jacking at the bottom of a falsework bent, rather than at the top. In such designs, two or more posts will be supported by a bottom cap, which will be supported by wedges or wedges over sand jacks set on the falsework footings.

Each post must be mechanically connected to the bottom cap to withstand a force of at least 2000 lb. The design force does not accumulate along the bottom cap, so the connection between the bottom cap and the falsework foundation is only required to resist 2000 lbs total, regardless of the number of posts supported. A single point of restraint will not provide adequate resistance in the transverse direction when the 2000 lb force is applied perpendicular to the beam, unless the connection is capable of resisting moment as well as shear. The most practical solution is to restrain the bottom cap at both ends, and both connections must be designed to resist (transfer) 2000 lbs.

As an alternative means of providing lateral restraint, the 2000 lb force may be carried from the bottom cap directly to the ground in the manner shown in Figure 4-12, *Application of 2000 Pound Load*.

If cap systems are used as discussed in Section 6-8, *Cap Systems*, all the caps in the cap system must be restrained for the 2000 lb load as discussed above for the single bottom cap.

Each falsework post must be mechanically connected to the top cap, and the connection must be designed to resist and comply with the following:

1. 1000 lb force applied at the top of the post will be:
   a. Applied at the top of each post regardless of its size, spacing, or loading; however, it will be assumed as acting on only one post at a time.
   b. Applied in any direction.
2. Lateral restraint must be effective in any horizontal direction.
3. For a bent in a highway median or in between railroad tracks, the restraint must be effective in all directions.
4. For falsework with bents parallel or at an angle to roadways or railroads, this requirement applies to all posts within the limits shown in Section 4-12.01, *Introduction*, but not less than two posts.

Contract Specifications, Section 48-2.02B(4), *Falsework – Design Criteria – Special Locations,* requires certain stringers to be mechanically connected to the cap. The connection must be designed to resist and comply with the following:

1. 500 lb force applied in any direction, including uplift
2. These connections must be installed and functional before traffic is permitted to pass under the falsework span.
3. For falsework stringers parallel or at an angle to roadways or railroads, where traffic does not pass under the stringers, but the stringer is within the limits shown in Section 4-12.01, *Introduction*, mechanically connect the exterior stringer to the cap. The connection must be capable of resisting a force in any direction, including uplift, of not less than 500 lbs.

Details showing the connection between stringer and cap, cap and post, and post and footing, must be shown on the shop drawings. All components must be designed so that the specified maximum allowable stresses in bending, shear, and bearing are not exceeded. The load duration factor, $\mathbf{C_D}$, for impact loading may be used to determine the allowable value of nails and bolts used in the connection:

- $\mathbf{C}_D$ = 1.6 for nailed and bolted connections only

4-12.05D Bracing

The *Contract Specifications*, Section 48-2.02B(4), *Falsework – Design Criteria – Special Locations,* require bolted connections when timber members are used to brace falsework bents over or adjacent to roadways and railroads:

1. For falsework with bents parallel or at an angle to roadways or railroads, this requirement applies to all bracing within the limits shown in Section 4-12.01, *Introduction*, but not less than one cross brace between two posts.
2. This requirement applies to bracing in the longitudinal as well as the transverse direction.
3. The bolt diameter must be at least 5/8-inch.
4. Substitution of bolts with coil rods is permitted if the root diameter of the coil rod is greater than or equal to the required bolt diameter. Also, the substituted coil rods must provide the capacity required for the connection. The term coil rod includes threaded coil rods, as well as threaded rods.
5. The brace must be bolted at both ends. It is not acceptable practice to use a bolt at one end of a brace and nails or lag screws at the other end.
6. Other fastener types may be used as intermediate fasteners in the center intersection of a diagonal brace. See Section 6-3.02, *Wood Cross Bracing.*

All components of the falsework system which contribute to horizontal stability and resistance to impact, except for bolts in bracing, must be installed at the time each element of the falsework is erected, see *Contract Specifications*, Section 48-2.03C, *Falsework – Erection*. Therefore, friction cannot be considered as contributing to the strength of the connection, at either the top or the bottom, because frictional resistance is not developed until a load is applied.

Bolts in bolted connections need not be installed when the falsework is erected to facilitate adjusting of the falsework to grade. However, if the Contractor elects to use nails in lieu of bolts as a temporary expedient, the nailed connection must be shown on the shop drawings, and the connection must be designed to resist the assumed horizontal load while the connection is in use.

When nails are used as temporary fasteners to facilitate grade adjustment, they should be replaced by bolts as soon as feasible, and in any case prior to placing concrete.

4-12.05D(1) Temporary Bracing

The *Contract Specifications*, Section 48-2.03A, *Falsework – Construction – General,* require the installation of temporary bracing as necessary to withstand all imposed loads during erection, construction, and removal of the falsework. While wind loads are to be considered in the design, the basic requirement is that the bracing must be adequate to "withstand all imposed loads." Under the specifications, the Contractor must determine the design load, which may not be less than the specified wind load for the height of falsework under consideration.

Details showing the temporary bracing, or other means of support provided to meet the intent of the specifications, must be shown on the shop drawings. Such details are a part of the design and must comply with all contract requirements even though the bracing or other means of support may be only "temporary" restraining devices.

4-12.05E Modified Design Load

The vertical load used for the design of posts and towers which support falsework adjacent to or over roadways and railroads must be modified to increase the factor of safety. This modified design load must comply with the following:

1. 150% of the load calculated in the usual manner
2. Applied to post loads only
3. For falsework with bents parallel or at an angle to the roadways or railroads, this requirement applies to all posts within the limits shown in Section 4-12.01, *Introduction*, but not less than two posts.

In the case of towers, the modified design load will be applied to all tower legs if any of the tower legs are within the limit shown in Section 4-12.01, *Introduction*.

If the load on falsework adjacent to or over a roadway or railroad will be increased by load transfer due to prestressing, the design vertical load for posts and towers will be either the actual (unmodified) load plus the additional load due to prestressing or 150% of the design load, whichever is greater.

4-12.06 Additional Requirements Over or Adjacent to Railroads

4-12.06A Introduction

In addition to the requirement in Section 4-12.05, *Requirements Over or Adjacent to Roadways or Railroads*, the design of falsework which is over or adjacent to railroads must comply with all the special requirements in this section as well. Moreover, the design must also comply with the current railroad guidelines.

4-12.06B Mechanical Connections

All falsework stringers that span over a railroad must be mechanically connected to the caps. The mechanical connection must be capable of resisting a 500 lb. load in any direction, including uplift on the stringer.

4-12.06C Bracing

The principal design requirement is that bracing for falsework bents located within 20 feet of the track centerline must be designed to resist the following:

- 5000 lb. or the assumed horizontal load, whichever is greater
- This requirement applies to both transverse and longitudinal bracing

In the specification context, the term “bent” means the overall length of the falsework bent regardless of the number of posts used. Typically, the 5000 lb. load will govern the design only in the case of relatively narrow structures where the bent consists of five, or fewer, falsework posts.

The load duration factor, $\mathbf{C_D}$, in the wood connections is determined as follows:

- 1.25 for the assumed horizontal load or 5000 lb. load
- 1.6 for wind load

4-12.06D Timber

For timber members:

1. All connections must be bolted
2. The bolt diameter must be at least 5/8-inch
3. Substitution of bolts with coil rods is permitted if the root diameter of the coil rod is greater than or equal to the required bolt diameter. Also, the substituted rods must provide the capacity required for the connection

The railroad will require solid end blocking when timber stringers are used regardless of the height-to-width ratio of the timber stringers.

The load duration factor, $\mathbf{C_D}$, in the wood connections is determined as follows:

- $\mathbf{C}_D = 1.25$ for the assumed horizontal load or 5000 lb load
- $\mathbf{C}_D = 1.6$ for wind load

4-12.06E Steel

For steel, the allowable compression, tensile, bending, and shear stresses are limited to:

$$F_b \leq 0.55F_y \tag{4-12.06E-1}$$

$$F_v \leq 0.35F_y \tag{4-12.06E-2}$$

where $\mathbf{F_b}$ = Maximum allowable compression, tensile, and bending stress

$\mathbf{F_v}$ = Maximum allowable shear stress

$\mathbf{F_y}$ = Minimum yield strength

4-12.06F Shop Drawings Over or Adjacent to Railroads

The design of falsework over or adjacent to railroads is subject to review and approval by the railroad company involved. To expedite approval, shop drawings submitted for railroad company review should conform to the following procedural requirements:

1. All design and construction details must be shown. If a reference is made to a standard plan or to a detail shown on a previously submitted drawing for another structure in the contract, such plans or drawings must accompany the submittal to the railroad.
2. When submitting only that portion of the falsework which is over or adjacent to the railroad, details of the adjacent falsework spans must be shown, as these spans will affect the design of the bents over or adjacent to the railroad.
3. Design features or details for more than one structure must not be shown on the same drawing.
4. The shop drawings must include a sketch showing the location of the temporary minimum horizontal and vertical clearance to the falsework.
5. All falsework clearances and clearances to equipment must be clearly shown. The vertical clearance is measured from the top of the track rail and horizontal clearances are measured from the centerline of the tracks.
6. All temporary structures and equipment within 25 feet of centerline of track must be shown on the shop drawings. Similarly, all temporary structures and equipment, which if they were to fall over would land within 25 feet of centerline of track, must be shown on the shop drawings.
7. All temporary structures and equipment within railroad right-of-way must be shown on the shop drawings. Similarly, all temporary structures and equipment,

which if they were to fall over would land within railroad right-of-way, must be shown on the shop drawings.

8. Soffit and deck overhang forming details should be included.

See also Section 2-4.02B, *Review Procedure when Railroad is Involved,* for additional information.

4-13 Waste Slabs

4-13.01 Introduction

A waste slab is a concrete slab finished to a smooth surface which is set to the soffit grade of a bridge superstructure. It is cast on compacted material in a fill or in a cut and becomes the bottom soffit form for the structure. On completion of the structure the fill or cut material along with the slab is removed to final cross section, see Figure 4-13, *Waste Slab*.

4-13.02 Considerations

Waste slabs are considered a construction method and not falsework as defined by the *Falsework Manual*. In order to check the adequacy of the slabs, the Structure Representative should require shop drawings as outlined in the *Contract Specifications*, Section 5-1.23B(2), *Shop Drawings*.

Some factors to be considered are:

1. Type of material under the slab
2. Amount and depth of compaction
3. Load on slab
4. Slab thickness
5. Slab must be wide enough to support exterior girder and overhang falsework
6. Finish must comply with *Contract Specifications*, Section 51-1.03C(2), *Forms* and *Contract Specifications*, Section 51-1.03F, *Finishing Concrete.*
7. Bond breaker between soffit slab and waste slab
8. Settlement (subsidence with time if on fill)
9. Bridge camber
10. Down drag on the bridge foundation piles due to fill
11. Columns and abutment must be protected from stains from the fill
12. Place barriers after the waste slab has been removed

13. Place approach slabs after the waste slab has been removed
14. Check Cal/OSHA to see if mining and tunneling regulations are applicable during fill removal after bridge is constructed.

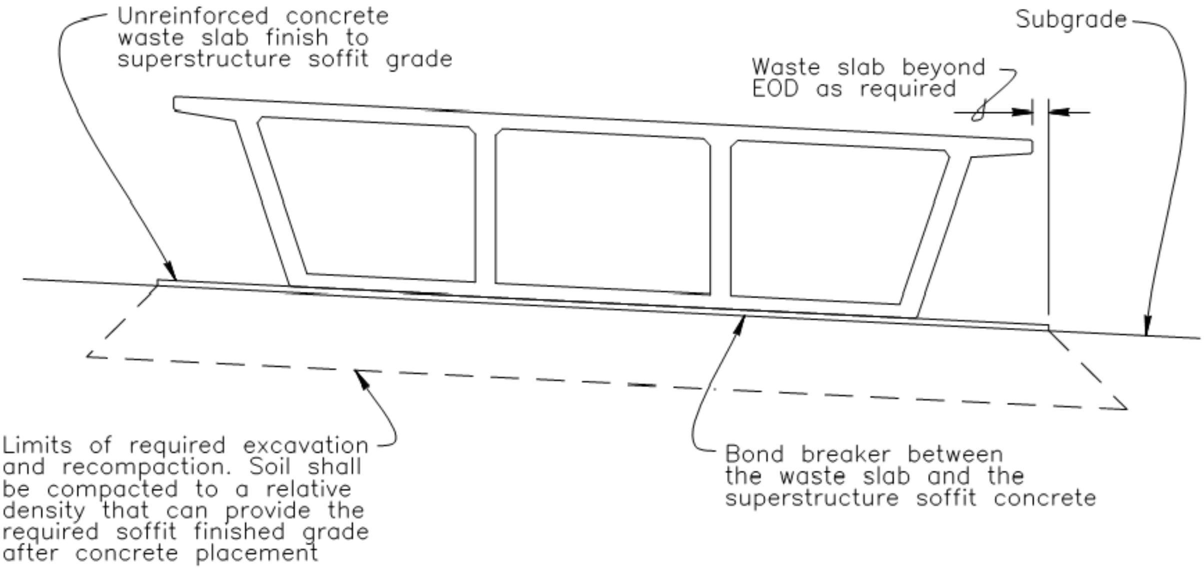


Figure 4-13. Waste Slab

4-14 Sand Beds

4-14.01 Introduction

A sand bed is a well compacted layer of sand designed to support the soffit joists in lieu of conventional falsework. The sand bed with the soffit plywood and joist is set to the soffit grade of a bridge superstructure. The sand bed is constructed on compacted material in a fill or in a cut and becomes the support for the bottom soffit form for the structure. On completion of the structure, the fill or cut material along with the sand bed and forms is removed to final cross section, see Figure 4-14, *Sand Bed*.

4-14.02 Considerations

Sand beds are considered a construction method and not falsework as defined by the *Falsework Manual*. In order to check the adequacy of the sand beds, the Structure Representative should require shop drawings as outlined in the *Contract Specifications*, Section 5-1.23B(2), *Shop Drawings*.

The sand bed is constructed such that the soffit joists have full bearing on the sand bed. The plywood is designed to be supported by the joist only. Although sand is placed and compacted between the joists, this sand is only intended to help distribute the plywood load evenly but is not intended to support the plywood.

Some factors to be considered are:

1. Type of material for the sand bed and under the sand bed
2. Amount and depth of compaction
3. Load on the sand bed from the joists
4. Thickness of sand bed
5. Sand bed must be wide enough to support exterior girder and overhang falsework
6. Finish must comply with *Contract Specifications*, Section 51-1.03C(2), *Preparation – Forms,* and *Contract Specifications*, Section 51-1.03F, *Finishing Concrete.*
7. Settlement (subsidence with time if on fill)
8. Bridge camber
9. Check plywood deflection based upon span between joists
10. Down drag on the bridge foundation piles due to fill
11. Columns and abutment must be protected from stains from the fill
12. Place barriers after the sand bed has been removed
13. Place approach slabs after the sand bed has been removed
14. Check Cal/OSHA to see if mining and tunneling regulations are applicable during fill removal after bridge is constructed.

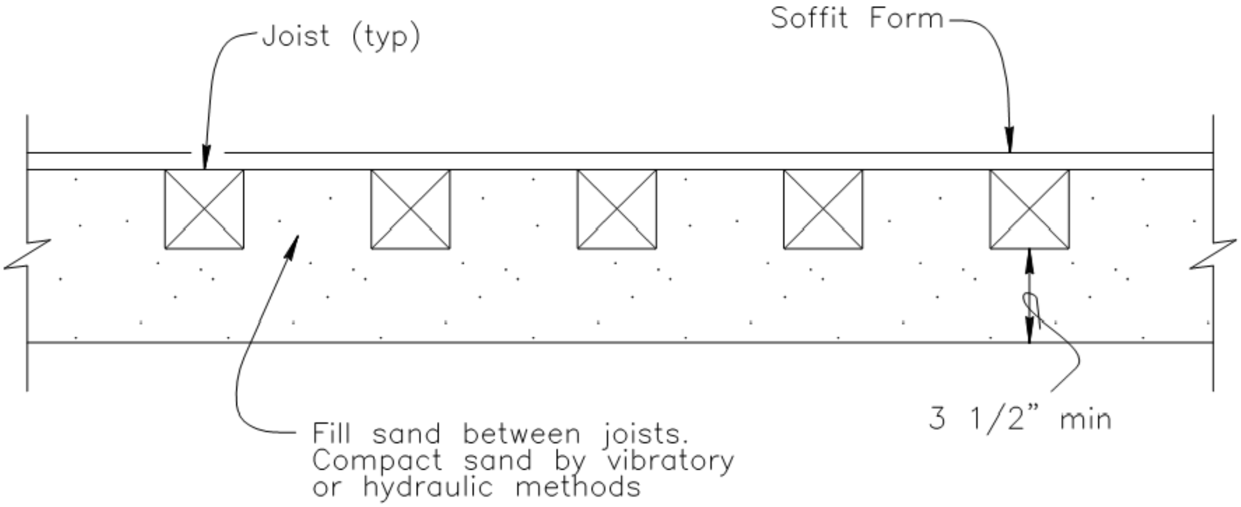


Figure 4-14. Sand Bed