SUPERSEDES BRIDGE DESIGN AIDS SECTION 4-10 DATED SEPTEMBER 2004

4-10 DESIGN OF STANDARD SLAB BRIDGE

Introduction

This Design Aid provides the following standard slab bridge designs:

Attachment A – Simple Span Slab Bridge Deck Reinforcement

Attachment B – Two-Span Slab Bridge Deck Reinforcement

Attachment C – Three-Span Slab Bridge Deck Reinforcement

Attachment D – Multi-Span Slab Bridge Deck Reinforcement

Attachment E – Slab Bridge Pile Spacing and Bent Cap Reinforcement

Attachment F – Slab Bridge Substructure Load

Attachment G – Slab Support Design Examples

The Attachments are developed based on AASHTO Load and Resistance Factor Design (LRFD) Specifications and Caltrans Amendments to the LRFD Specifications. All Article numbers shown in this Aid correspond to the numbers in the LRFD Specifications. If the assumptions made in the development of these attachments are not valid, then site-specific design will be required.

Design Assumptions and Limitations

Strip Width

The Attachments have been developed using the "Approximate Method of Analysis" as outlined in Article 4.6.2. The equivalent width of a longitudinal strip (E) in feet, for both shear and moment design, is based on Article 4.6.2.3 and given by:

$$E = 7 + 0.12\sqrt{L_1 W_1} \leq \frac{12W}{N_L}$$

Since the strip width is dependent on the span length as well as the bridge width, a width of 30 ft has been assumed to calculate the strip width for a given span.

Span Length

The Attachments have been developed for span lengths (L) ranging from 16 ft to 44 ft, and for the span configurations shown in Attachment F. The length of D-Span (end span) is 75% of a typical span length.

Slab Thickness

Minimum slab thickness is determined in accordance with the requirements in Article 2.5.2.6.

Bridge Skew

The Attachments are valid for skews up to 50°. In bridges with a skew, piles may have to be added to support the obtuse corners of the slab. In general, skews over 30° are strongly discouraged due to seismic concerns.

Abutment

Abutment designs should be based on the recommendations in Memo to Designers 5-1 and 5-2 with appropriate modifications per Caltrans Seismic Design Criteria (SDC).

Effective longitudinal force at the abutment is obtained by dividing the total force by the effective abutment width.

Piles

Only Standard Class 90 and Class 140 piles are considered.

The maximum unsupported length of column/pile extension, including the effects from scour, is assumed to be 25 feet.

The piles are founded in compact sandy soil (or better) and/or stiff clay (or better).

Seismic forces and forces due to stream current and debris effects are not considered.

Pile Spacing

The dead and live load reactions are assumed to be equally distributed among all the piles at a support. This assumption is reasonable for overhang lengths from 0.20 to 0.40 times the spacing

between the piles. An overhang length greater than 0.4 times the pile spacing is not recommended.

The factored pile capacities are 126 kips and 196 kips for Class 90 and Class 140 piles respectively. Pile spacing is calculated by dividing factored pile capacity by the factored demand from either Strength I or Strength II limit states – whichever governs.

Minimum center-to-center pile spacing is limited to 4 ft (or 3 times the diameter of a 16-inch diameter CIDH pile); maximum pile spacing is limited to 12 ft.

Bent Cap

Cap shear capacity has been calculated using the simplified method as outlined in Article 5.8.3.4.1 and 5.13.3.6. Drop caps are required for all continuous slab bridges of span length 28 ft and smaller to provide adequate punching shear capacity.

Exposure Condition

Class 2 exposure condition has been assumed to verify rebar spacing in the superstructure in accordance with Article 5.7.3.4.

Concrete Strength

The Attachments are developed based on a concrete compression strength $f'c$ =3600 psi.

Instruction to Design Charts

Slab Reinforcement

The Attachment A, B, C and D provide top and bottom longitudinal and transverse reinforcement for different span configurations. When inserting the Standard Detail Sheet "*xs1-220*" (Slab Reinforcement Details) to the bridge plans, the transverse reinforcement and distribution reinforcement shown on this sheet need to be adjusted accordingly.

Superstructure Camber

The camber values are provided in the Attachments and conform to the requirements of Article 5.7.3.6.2.

Camber calculations include the self weight of two Type 736 concrete barriers and the dead load from future overlay, but do not include the loads from any utilities and from an additional ½ -inch. concrete overlay placed in Climate area III.

Approximate Superstructure Quantities

The Attachments A, B, C and D also provide the approximate slab concrete volume and steel rebar weight for one lineal foot of slab width. The reinforcement for caps and end diaphragms as well as the concrete extending outside the slab limits is not included in the Attachments.

Pile Layout

Attachment E provides the pile spacing for both Class 90 piles and Class 140 piles at the Bents as well as at the Abutments. The total number of piles is calculated as:

$$Number\ of\ piles = \frac{\left(Abutment\ or\ bentcap\ length - 2 \times overhang\ length\right)}{pile\ spacing} + 1$$

The length of a skewed abutment or bent cap is given by:

$$\frac{Abutment\ or\ bentcap\ length}{cosine\ of\ the\ skew\ angle}$$

The number of piles is rounded up to a whole number.

Bent Cap Details

The Bent Cap Details for different skew angles are shown in Attachment E. For bridges with span lengths less than or equal to 28 ft, a 2 ft deep by 3 ft wide bent cap is used in calculations. For all other span lengths, an effective bent cap having the same depth as that of the slab, and a width equal to the pile diameter plus twice the slab depth is used.

For bridges with span lengths less than or equal to 28 ft, the longitudinal bent cap reinforcement consists of 4 bars each at the top and bottom. For all other spans, the cap reinforcement consists of 6 bars each at the top and bottom.

Support Reaction

The support (pile) reactions under various load cases are provided in Attachment F.

To calculate the total load per pile at the Service Limit State, calculate the reaction due to each of the following load groups:

a) Self weight of the slab: Multiply the slab self weight coefficients in the table by the effective slab width per pile (which usually is the pile spacing)

b) Dead load of barrier rails and utilities: Multiply the dead load (expressed in weight per unit length) of the barrier rails and utilities by the uniform load coefficient. Distribute this load equally to all piles at the support.

c) Dead load from wearing surface and added overlay: Determine the effective slab width for each pile; calculate the weight per unit length of wearing surface and overlay. Multiply this load by the uniform load coefficient.

d) Load due to the self weight of the bent cap: Multiply the coefficient in the table by effective slab width per pile.

e) Live Load – HL93 truck and lane load: Calculate the lane factor – ratio of the effective slab width per pile to the lane width per Article 4.6.2.3. Multiply the coefficient in the table by the lane factor.

The pile demands under Strength Limit States can be calculated by multiplying these loads with appropriate load factors. For Strength II Limit State, the demand due to the permit vehicle (P-15 truck and other P-Family trucks) can be obtained in the same manner as that for HL93 Truck.

Additional Considerations

Seismic Considerations

The Attachments are developed without explicit consideration of seismic load effects. The design engineer shall verify that the bridge design based on the Attachments also meets the requirements in Caltrans SDC.

Pile Details

The Standard Detail Sheet "*xs1-230*" (Slab Bridge Pile Details) provides three types of 16 inches diameter concrete pile details that may be used to support slab bridges. The detail for the Cast-In-Steel-Shell (CISS) pile shows the steel shell terminating below the ground line. If this

detail is adequate for design considerations, then Caltrans permits the contractor to extend the shell up to 2 to 4 inches below the soffit. The design engineer should convey this information to the specifications engineer through a "Memo-to-specifications engineer". If a full height steel shell is required from design considerations, then "*xs1-230*" should be modified accordingly to show the shell terminating 2 to 4 inches below the soffit line.

Pile Strength and Ductility

The standard pile details shown in "*xs1-230*" may not have sufficient longitudinal and transverse reinforcement to provide adequate strength and ductility for Extreme Event II (Seismic) Limit State. The design engineer should assess the strength and ductility of piles and make suitable modifications as required to meet SDC requirements.

Pile Top Connection

The top of the pile extensions/columns may either be fixed or pinned to the slab or bent cap.

When the top of the pile extension/column is fixed, the designer should ensure that the pile reinforcement has adequate anchorage into the bent cap or the slab. The pile-slab or pile-bent cap connection should be properly engineered and detailed to provide adequate ductility and capacity. The designer should also investigate the need for additional slab and bent cap reinforcement in accordance with SDC.

Hinges

In new slab bridges, if hinges are required, then they should be located at the bents as shown in Standard Detail Sheet "*xs1-210*" (Slab Hinge Details). These hinges shall be properly engineered so that they are adequate for all applicable Strength, Service and Extreme Limit States. The design engineer shall verify the adequacy of the details shown, provide joint seal data, "A" bar size, and elastomeric bearing pad size on the plans, and make suitable changes prior to inserting this sheet as a part of structure plans.

In-span hinges should be avoided in new slab bridges. Such hinges have been used in the past to provide an unbroken soffit line for aesthetics. However, since slab bridges are typically not used as over-crossings/under-crossings, the relative merits of aesthetics and structural performance should be carefully considered.

When widening slab bridges with hinges, the design engineers should, in general, match new hinge locations with those on the existing bridge. If an existing slab bridge has a steel hinge, then the design engineer should consider incorporating a concrete hinge in the widening and insert

"*xs1-210*" with the necessary modifications. The design engineer should verify the adequacy of hinge details, including seat length, for all load cases. In some cases, when an existing slab-bridge with in-span hinges is being widened, a longitudinal joint may be required if the design engineer chooses not to match existing hinge locations. Longitudinal bridge joints are strongly discouraged since they lead to performance and maintenance problems. Hence, this option should be considered only as a last resort.

Makeup of Plans

General Plan

See Section 3, Bridge Design Details (BDD) Manual for details on General Plan. The "General Notes" are shown on the Slab Reinforcement Details Sheet *"xs1-220"*. These notes should be modified to conform to current standards.

Deck Contour

See Section 4, BDD Manual.

Foundation Plan

See Section 5, BDD Manual.

Abutments and Bent Details

See Section 6 & 7, BDD Manual. Wingwalls details per Standard Plan B0-1 will generally be adequate. Dropped bent caps should be fully detailed showing the plan, elevation and section. For aesthetic reasons, the dropped portion of a bent cap should be terminated at least 1'-0" from edge of deck. For flush caps, the width of stirrups must be indicated.

Deck Details

Plan view of both top and bottom slab reinforcement should be shown. The details should show the length, total number and placement data for each class of main reinforcing bars. Also show

the typical section, the camber diagram, main reinforcing bars and a diagram for payment of concrete. A longitudinal deck sectional view is unnecessary since it is shown on *"xs1-220"*.

Slab Reinforcement Details

Insert *"xs1-220"*, with appropriate modifications, as a part of the Plans for every slab bridge.

Slab Hinge Details

Insert *"xs1-210"*, with appropriate modifications, as a part of the Plans when a hinge is required.

Railing Details

Refer to the Standard Plans or insert appropriate sheets.

Standard Plans

The following sheets will always be required:

A62-C "Limits of Payment for Excavation and Backfill Bridge";

B0-1 and B0-3 "Bridge Details".

Other sheets should be referenced as and when required.

Log of Test Borings

Insert this sheet.