Chapter 23

BRIDGE WIDENING AND REHABILITATION

SCDOT BRIDGE DESIGN MANUAL

April 2006
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CHAPTER 23

BRIDGE WIDENING AND REHABILITATION

23.1 BRIDGE WIDENING

23.1.1 Introduction

It may be necessary to widen existing bridges for a variety of reasons:

1. The existing bridge may provide an inadequate roadway width.

2. The project may be adding lanes to a highway segment to increase the traffic-carrying capacity of the facility.

3. A bridge may be widened to add an auxiliary lane across the structure (e.g., increasing the length of an acceleration lane for a freeway entrance, adding a weaving segment at the interior of a cloverleaf interchange).

A bridge widening can present a multitude of difficult issues during the design stage, during construction, and throughout its service life. Special attention is required to both the overall design and the details of the widening to minimize construction and maintenance problems. The widening of a structure should also be designed in coordination with the appearance and function of the existing bridge.

This Section presents Department guidelines for widening existing bridges. The following briefly summarizes the basic objectives in bridge widening:

1. Do not perpetuate details that have proven to be fatigue prone. Examples include welded cover plate ends and other details with a fatigue resistance lower than Detail Category C or C’ (i.e., Detail Categories D through E’).

2. Match the structural components of the existing structure, including splice locations, as practical.

3. With respect to fixity, match the existing bearing function. The rotational and deflection characteristics of the existing bearing type should be considered when selecting new bearings.

It is not normally warranted to modify the existing structure solely because it was designed to earlier Specifications and does not satisfy the provisions of the LRFD Bridge Design Specifications. Bridges designed to the earlier AASHTO Standard Specifications are usually acceptable with respect to the adequacy of their structural design. However, the bridge designer shall evaluate the need to seismically retrofit the existing bridge. The degree of knowledge for
seismic design increases with each subsequent seismic event; therefore, reviewing existing bridges within the context of the latest seismic requirements may be justified.

### 23.1.2 Existing Structures with Substandard Capacity

Typically, existing bridges to be widened should be designed based on the original design. The SCDOT Bridge Maintenance Office, which has the responsibility for inspecting all in-service bridges and maintaining all State-owned in-service bridges, should always be consulted on the condition and the load capacity of the existing structure. Based on this information, the designer may determine that the existing structure should be strengthened to the same load-carrying capacity as the widened portion. For the evaluation, the following should be considered, as appropriate:

- cost of strengthening existing structure;
- physical condition, operating characteristics, and remaining service life of the structure;
- seismic resistance of structure;
- other site-specific conditions;
- width of widening; and
- traffic accommodation during construction.

### 23.1.3 Girder Type Selection

In selecting the type of girder for a structure widening, the widened portion of the structure should be a construction type and material type consistent with the existing structure, as practical. Materials used in the construction of the widening should have the same thermal and elastic properties as the existing structure. Avoid mixing concrete and steel beams in the same span. One exception to this is for an existing conventionally reinforced concrete T-beam structure. In this case, it is preferable to use prestressed concrete I-beams or steel rolled beams for the widened portion.

### 23.1.4 Attaching Bridge Decks

#### 23.1.4.1 Existing Bridge Deck

The designer must evaluate the need to rehabilitate or replace the existing bridge deck as part of the bridge widening project. Section 23.2 discusses the evaluation of an existing bridge deck.

#### 23.1.4.2 Longitudinal Expansion Joints

Longitudinal expansion joints in bridge decks between a bridge widening and an existing bridge are often a continuous source of bridge maintenance problems and are a potential safety hazard if they are located within the riding surface of the deck. Therefore, as a general policy, no
longitudinal expansion joints should be detailed, except for locations where concrete barrier rail or raised concrete median is placed on each side of the joint.

23.1.4.3 Lapping Reinforcing Steel

A positive attachment of the widened and existing decks by lapping reinforcing steel usually provides a better riding deck, presents a better appearance, and reduces maintenance problems in comparison to longitudinal expansion joints. A positive attachment of the old and the new decks should be made for the entire length of the structure.

In some cases, it may be desirable to use mechanical couplers or an epoxy-resin anchorage system instead of lapping reinforcing steel. Lapped reinforcing steel may be more expensive than other options because of the need to provide adequate bond length. For example, mechanical couplers may be more cost effective than removing additional existing concrete to expose more length of reinforcing bar to obtain the necessary lap splice length.

23.1.4.4 Requirements

The following requirements should be considered when widening an existing girder/beam and deck-type structure:

1. **Large Overhangs.** Structures with large overhangs, where adequate room exists between the outside edge of deck and the exterior edge of the top flange, should be widened by removing the concrete from the overhang to a width sufficient to develop adequate length for lapping the original transverse deck reinforcing steel to that of the widening.

2. **Small Overhangs.** Structures with small overhangs, where removal of the overhang to the exterior edge of the top flange will not provide sufficient bond length, should be either doweled to the widening or have transverse reinforcing steel exposed and extended by mechanical lap splice.

3. **Existing Barrier.** Where the existing deck will not be overlaid with concrete, the deck should be removed to at least the existing gutter line.

4. **Longitudinal Construction Joints.** Longitudinal construction joints should not be located over the beam flanges. Longitudinal construction joints should preferably be aligned with the permanent lane lines or located in the shoulder area of the deck. These joints tend to be more visible than the pavement markings during adverse weather conditions.

5. **Deck Loading.** Removal of the deck past the outside beam line (i.e., to somewhere between the fascia girder and the first interior girder) will result in a temporary cantilever slab condition. The designer must ensure that the temporary cantilever deck can resist the loadings anticipated during construction.
6. **Deck Removal.** A 1-in vertical saw cut shall be made in the existing slab where the slab is to be removed.

### 23.1.5 Closure Pours to Counteract the Effects of Dead-Load Deflection

Typical SCDOT practice is to use a closure pour between the existing bridge and the widened portion.

Unless the widened structure is completely prefabricated, deflection of the girders or beams will occur due to superimposed dead loads, such as the deck slab, diaphragms, barriers, etc. If proper provisions are not made to accommodate the dead load deflection, construction and maintenance problems will ensue. Where the deflection from the deck slab weight exceeds ½ in, a closure pour shall be used to complete the attachment to the existing structure. When a closure pour is used:

- stay-in-place forms shall not be used under the closure pour,
- diaphragms between new and existing construction shall not be rigidly connected until after the new deck is poured, and
- reinforcing steel shall not be tied or coupled to the existing reinforcing steel until after the new deck is poured.

A closure pour serves two useful purposes: It defers final connection to the existing structure until after the deflection from the deck slab weight has occurred; and it provides the width needed to make a smooth transition between differences in final grades that result from theoretical versus actual deflections or construction tolerances.

Considering the effects of dead-load deflection, two general groups of superstructure types can be distinguished:

- precast concrete beam or steel girder construction, where the largest percentage of deflection occurs when the deck concrete is placed; and
- cast-in-place construction (e.g., flat slab bridges), where the deflection occurs after the falsework is released.

In the first group, dead-load deflection after placing the deck is usually insignificant but, in the second group, the dead-load deflection continues for a lengthy time after the falsework is released. In conventionally reinforced concrete structures, approximately ⅔ to ¾ of the total deflection occurs over a four-year period after the falsework is released due to shrinkage and creep. A theoretical analysis of differential deflection that occurs between the new and existing structures after closure will usually demonstrate that it is difficult to design for this condition. Past performance indicates, however, that theoretical overstress in the connection reinforcing has not resulted in maintenance problems, and it is generally assumed that some of the additional
load is distributed to the existing structure with no difficulty, or its effects are dissipated by inelastic relaxation. Good engineering practice dictates that the closure width should relate to the amount of dead load deflection that is expected to occur after the closure is placed. A minimum closure width of 3 ft is recommended.

23.1.6 Vehicular Vibration During Construction

All structures deflect when subjected to live loading, and many bridge widenings are constructed with traffic on the existing structure. Fresh concrete in the deck is subjected to deflections and vibrations caused by traffic. Studies such as NCHRP 86 Effects of Traffic-Induced Vibrations on Bridge-Deck Repairs have shown that:

- reinforced concrete is not adversely affected by jarring and vibrations of low frequency and amplitude during the period of setting and early strength development;

- traffic-induced vibrations do not cause relative movement between fresh concrete and embedded reinforcement; and

- investigations of the condition of widened bridges have shown the performance of attached widenings, with and without the use of a closure pour, to be satisfactory.

Therefore, no special measures other than those described in Section 23.1.5 must be taken to prevent movement and vibration during concrete pouring or curing.

23.1.7 Substructure

Generally, new interior bent substructure units required to support the bridge widening are not connected to the existing substructure. Not connecting the new substructure to the old avoids damage to the substructure components due to differential settlement. However, if the new substructure unit consists of one column, the new substructure may be connected to the existing substructure, provided that suitable provisions are made in the design and details to prevent differential settlement. The effects of excavation adjacent to existing substructures shall be considered. The existing substructure shall be cleaned and textured if it is visible to the public. Consult with the Bridge Maintenance Office on any needed repair to exposed reinforcing steel and spalls.

23.1.8 Superstructure

The spacing between the existing exterior girder and the adjacent new girder shall be equal to or less than the girder spacing of the existing span. New diaphragm spacing for widenings shall be consistent with the existing diaphragm spacing. For widenings using a single girder system, a minimum of one interior diaphragm is required. With the exception of end diaphragm connections to existing beams at simply supported spans, field welding to the existing beams is
prohibited. On the existing deck, detail the same expansion joint type as that used on the new deck.

23.1.9 **Design Criteria (Historical Background)**

For bridge widenings, the designer should be aware of the historical perspective of design criteria, such as live loads, allowable stresses, etc., when analyzing an existing structure. For information on specific structures, see the as-built plans, old special provisions, any documentation of modifications made after original construction, and the appropriate editions of the AASHTO *Standard Specifications*.

Throughout the years, modifications to steel beam sections have occurred. Designers should refer to the construction year AISC steel tables for beam properties, steel strength, and other data.

23.1.10 **Clearances**

Existing horizontal and vertical clearances shall be maintained unless the existing clearance is greater than the minimum clearance required for a new structure.
23.2 BRIDGE REHABILITATION

23.2.1 Responsibilities

Typically, the SCDOT Bridge Maintenance Office and Bridge Design Section coordinate on the design of bridge rehabilitation projects depending on the workload of each Unit. Where the Bridge Design Section is responsible for the bridge rehabilitation project, the bridge designer should seek input from the Bridge Maintenance Office for assistance.

23.2.2 Project Identification Process

The Bridge Maintenance Office identifies bridge rehabilitation and replacement projects.

23.2.2.1 SCDOT Bridge Management System

The SCDOT Bridge Maintenance Office has the responsibility for running the SCDOT Bridge Management System (BMS). It uses both the National Bridge Inspection (NBI) data and additional detailed bridge data. This system is used as a tool along with input from Department management and the Districts in making decisions regarding:

- preservation,
- rehabilitation, and
- replacements.

23.2.2.2 National Bridge Inspection Standards (NBIS)

The National Bridge Inspection Standards (NBIS), a nationwide inspection and inventory program, is intended to detect structural problems. The Federal Highway Administration has promulgated regulations that each State Department of Transportation must meet. The following presents a brief discussion on the operational requirements of the NBIS:

1. **Frequency of Inspections.** Each bridge must be inspected at periodic intervals based on its condition and type.

2. **Qualifications of Personnel.** The Federal regulation lists the minimum qualifications for all bridge inspection personnel.

3. **Inspection Procedures and Reports.** Each State must have a systematic method for conducting field inspections and reporting its findings.

4. **Records.** Each State must have a systematic means of entering, storing, and retrieving all bridge inspection data.
5. **Ratings.** All bridges are rated according to their load-carrying capacity. This includes both the Operating and Inventory Ratings. This information assists in the posting, the issuing of special overload permits, and the scheduling for rehabilitation or replacement.

### 23.2.2.3 SCDOT Bridge Inspection Program

The Bridge Maintenance Office is responsible for collecting, maintaining, and reporting bridge inspection information and for ensuring that the SCDOT Bridge Inspection Program complies with the requirements of the NBIS. The South Carolina Bridge Inspection Program provides the data that, through the use of the Sufficiency Rating, identifies the overall sufficiency of every bridge open to the public in the State of South Carolina.

### 23.2.2.4 Sufficiency Rating

The Sufficiency Rating formula is a method of evaluating highway bridge data by calculating several factors (structural adequacy, safety, serviceability, functional obsolescence, and special reductions) to obtain a numeric value that is indicative of the bridge’s sufficiency to remain in service and its funding eligibility. The result of the Sufficiency Rating formula is a percentage in which 100 is an entirely sufficient bridge and 0 is an entirely deficient bridge.

### 23.2.3 Rehabilitation Strategy

Bridge rehabilitation design involves the following basic steps:

1. Perform a field investigation of the existing bridge.
2. Collect the available data on the existing bridge (e.g., as-built plans, bridge inspection data, traffic volumes).
3. Identify the necessary condition surveys and tests (e.g., coring, chain drag, chloride analysis, identifying fracture-critical members).
4. Evaluate the data from the condition surveys and tests.
5. Select the appropriate bridge rehabilitation technique(s) to upgrade the bridge to meet the necessary structural and functional objectives.

For those bridge rehabilitation projects designed by the Bridge Design Section, the bridge designer should seek input from the Bridge Maintenance Office to implement the bridge rehabilitation strategy.
23.2.4 **Bridge Decks**

23.2.4.1 **Evaluation**

Certain factors are symptomatic indicators that a bridge deck may need to be rehabilitated or replaced. Some examples are:

- extensive delamination,
- exposed reinforcing steel, and
- spalls.

When considering a bridge deck for replacement or rehabilitation, the Bridge Design Section requests a number of tests to gather information on the deck’s condition. The gathered information allows the designer to determine whether deck rehabilitation or deck replacement would be more effective and, if the choice is rehabilitation, the information allows the determination of the appropriate level of treatment.

The Bridge Design Section requests the following information to perform a deck evaluation:

- a plot locating existing delaminations, spalls, and cracks;
- measurement of the depth of cover on the top mat of reinforcing steel on a grid pattern;
- sampling and laboratory analysis to determine the existing levels of chloride contamination; and
- deck concrete compressive strength assessed through destructive testing of deck core samples.

23.2.4.2 **Condition Assessment Tests**

23.2.4.2.1 **Visual Inspection**

The following applies to visual inspections:

1. **Description.** A visual inspection of the bridge deck should establish:
   
   - the approximate extent of cracking, delamination, spalling, and joint opening;
   - evidence of any corrosion;
   - evidence of pattern cracking, efflorescence, or dampness on the deck underside;
   - rutting of the riding surface and/or ponding of water;
• operation of deck joints;

• functionality of deck drainage system; and

• bridge rails and guardrail-to-bridge-rail transitions meeting current SCDOT standards.

2. **Purpose.** The visual inspection of the bridge deck will achieve the following:

• By establishing the approximate extent of cracking, corrosion, delamination, and spalling (and by having evidence of other deterioration), the bridge designer can determine if a more extensive inspection is warranted.

• The inspector will identify substandard safety appurtenances.

3. **When to Use.** Use for all bridge deck evaluations.

4. **Analysis of Data.** Pattern cracking, efflorescence, or dampness on the deck underside suggest that this portion of the deck is likely to be highly contaminated. In addition, the designer should consider:

• traffic control,
• timing of repair,
• age of structure,
• average daily traffic,
• slab depth,
• structure type,
• depth of cover to reinforcement, and
• seismic factors.

23.2.4.2.2 Delamination Testing or Sounding

The following applies to delamination testing or sounding:

1. **Description.** Establishes the presence of delamination, based on audible observation, by chain drag or hammer. Based on the observation that delaminated concrete responds with a “hollow sound” when struck by a metal object.

2. **Purpose.** To determine the location and areas of delamination.

3. **When to Use.** Use for all bridge deck evaluations, except where asphalt overlays prevent performance of the test.

4. **Analysis of Data.** Based on the extent of the bridge deck spalling, the following will apply:
• 5% delamination of surface area is a general guide for considering remedial action, and

• 10% delamination is a general guide for considering bridge deck replacement.

23.2.4.2.3 Coring

The following applies to coring:

1. **Description.** 2-in or 4-in diameter cylindrical cores are taken. In decks with large amounts of reinforcement, it is difficult to avoid cutting steel if 4-in diameter cores are used.

2. **Purpose.** To establish strength, composition of concrete, crack depth, position of reinforcing steel.

3. **When to Use.** Use for all bridge deck evaluations.

4. **Analysis of Data.** Less than 2 in of concrete cover is considered inadequate for corrosion protection. Less than 3 ksi compressive strength of concrete is considered inadequate. If compressive strengths are less than 3 ksi, the designer must obtain a determination from the State Bridge Design Engineer whether to proceed with the deck rehabilitation or to proceed with a deck replacement. The choice of core locations can have a significant impact on the findings.

23.2.4.2.4 Chloride Analysis

The following applies to chloride analysis:

1. **Description.** A chemical analysis of pulverized samples of the bridge deck concrete extracted from the deck or by in-place drilling.

2. **Purpose.** To determine the chloride content profile from the deck surface to a depth of about 3 in or more.

3. **When to Use.** Use for all bridge deck evaluations. Take chloride samples at three to five locations per span from each span 100 ft or less in length. Increase the number of samples for longer spans.

4. **Analysis of Data.** The “threshold” or minimum level of water-soluble chloride contamination in concrete necessary to corrode reinforcing steel is 1.2 lbs/yd³ or 0.03% chloride by weight. Chloride concentrations equal to or greater than this value above the top reinforcing mat require the removal of at least enough concrete so that the remaining concrete contamination is below the threshold.
Threshold or greater chloride concentrations at the level of the top reinforcing mat require either 1) hydro-demolition to remove enough concrete to ensure that the remaining concrete is below the threshold values, or 2) deck replacement.

Threshold contamination or worse at or near the level of the bottom mat of reinforcing steel requires deck replacement.

23.2.5 Bearing Replacement

Often, the existing bearings may only need to be cleaned and/or repositioned. Extensive deterioration, or frozen bearings, may indicate that the design should be modified. A variety of elastomeric devices may be substituted for sliding and roller bearing assemblies. If the reason for deterioration is a leak in the deck joint, then the deck joint should be resealed or rehabilitated.

Rocker bearings and elastomeric bearings should not be mixed on the same interior bent, due to differences in movement.

If the bearings are seriously dislocated, their anchor bolts are badly bent or damaged, or the beam seats or pedestals are structurally cracked, then the bridge may have a system-wide problem, which is usually caused by temperature or settlement. All of these items should be investigated and evaluated.

The bearing design may require alteration if warranted by seismic vulnerability. Damaged or malfunctioning bearings can fail during an earthquake. In addition, steel rocker and roller bearings perform poorly because rocker bearings can easily tip over when their limits are exceeded during a seismic event and rollers roll freely. One option is to replace these bearings with prefabricated steel-reinforced elastomeric bearings. To maintain the existing beam elevation, either a steel assembly is inserted between the beam seat and the elastomeric bearing, or the elastomeric bearing is seated on a new concrete pedestal. Construction of new concrete pedestals may create significant additional traffic control costs. Existing anchor bolts that extend into a new pedestal from the top of the bent may be considered to assist in resisting the horizontal interface shear between the new pedestal and the existing interior bent. In both cases, the beam should be positively connected to the substructure by anchor bolts, either directly or indirectly.

See Chapter 21 for more information on bearings.

23.2.6 Seismic Retrofit

Bridges that are selected for seismic retrofitting shall be investigated for the same basic criteria that are required for all new bridges, including minimum support length and minimum bearing force demands. This evaluation will be based on the SCDOT Seismic Design Specifications for Highway Bridges. Specific details for seismic retrofitting may be found in the Seismic Design and Retrofit Manual for Highway Bridges, FHWA, latest edition.
Minor seismic retrofit will usually be limited to seismic restrainers, isolation bearings, and increasing the support length of beam seats. For the most part, the minor work will be limited to work at or above the beam seats.

Major seismic retrofit includes such items as strengthening columns, interior bents, bent caps, etc. It will generally include work below the level of the beam seats and may include work that requires cofferdams. SCDOT prepares cost estimates that compare the costs of a retrofit versus total replacement (including life-cycle costs). SCDOT then coordinates with FHWA to determine the project approach.