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Guide for Widening Highway Bridges

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Guide for Widening Highway Bridges

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Guide for Widening Highway Bridges

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Many highway bridges become functionally obsolete due to inadequate width before they become structurally deficient. Widening is generally more economical than complete replacement. Thus, there is a mandate to share the results of research and experience pertaining to bridge widening. This guide discusses technical issues related to the widening of concrete bridges and bridges with concrete decks. The primary focus of this document is on bridge decks, even though substructure issues are raised and discussed. The effects of differential movements between the existing and new portions are discussed, including movements due to traffic on the existing structure during construction. General recommendations are made pertaining to the choice of structure type, design details, and construction methods and materials.

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Keywords: bridge decks; bridge widening; bridges (structures); concrete construction; deflection; formwork (construction); reinforced concrete; reinforcing steel; substructure; superstructure; traffic vibration.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Design and construction engineers should investigate several potential issues if a bridge is to be considered for widening. These include retention of bridge elements, traffic control, structural constraints, economy and feasibility, expected increase in traffic volume, life span, and construc-

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tion limitations. Certain elementary procedures should be followed to study the feasibility of widening. These include:

- a) Review the drawings and specifications of the original structure.
- b) Review any revisions of engineering documents (for example, plans, specifications, and design calculations) that might have been approved during the original construction.
- c) Thoroughly inspect the structure and note changes to in-place conditions, such as deterioration of structural members due to environmental factors (for example, deicing salts, weathering, and collision of heavy trucks).
- d) Obtain additional subsurface information to accommodate increased superstructure loads, including soil borings.
- e) Review previous changes or upgrades to the structure.
- f) Perform structural analysis with allowance for existing deterioration to confirm that the existing elements are adequate for increased loads (due to widening and compliance with current design standards). If the existing elements are part of the replacement, all possible geometric properties need to be considered.

One of the first considerations for widening a bridge is to determine whether to retain structurally adequate parts of the bridge deck. Entire bridge deck replacement should be considered if the bridge deck is severely deteriorated, the existing bridge deck will become less than a half of the new bridge deck width, or both (Seible et al. 1991; “Operation Bridgeguard” 1992). If the bridge deck, or a portion of it, is to be retained and connected to a new deck, the design should provide for bending moment and shear transfer through the longitudinal joint between the new and old portions of the bridge deck. The steel passing through the construction joint should be protected from possible increases in corrosion potential between the old and new concrete.

Another important matter is the consideration of whether substructures, such as footings, pier caps, and abutments, should be widened to accommodate widening a superstructure. Potential interaction between the new substructure and the existing substructure should be considered. The design professional should be aware of possible problems that could occur when a bridge is widened on both sides. In most cases, the existing portion is trapped between new sections, making it difficult to replace the middle section.

1.2—Scope

This document provides design professionals and constructors with general guidelines for bridge widening. The widening of highway bridges is commonly conducted to improve the functionality of existing structural systems. Several factors contribute to this demand:

- a) Increased traffic volumes requiring additional lanes
- b) Safety hazards of narrow bridges requiring wider shoulders
- c) Provision for bikeways and pedestrian walkways

Government-funded programs are enabling public agencies to widen many functionally obsolete bridges as needed to improve safety. If a bridge was designed for current live loads and has not deteriorated appreciably, widening is likely more cost-effective than complete replacement.

It is imperative to perform in-depth nondestructive testing (NDT) and invasive testing to quantify the level of existing concrete deterioration and section losses in existing sections, and design protection methods to prevent future deterioration prior to investing in widening a structure.

Many problems unique to bridge widening are not encountered in new bridge work. Failures or serious maintenance problems can be created by misunderstanding these problems. Each bridge widening is unique.

This guide emphasizes construction practices, but because construction sequence, structure type, framing details, and other decisions critical to the success of the work are determined during the design phase, some discussion of design concepts must be included. Structural analysis and design for widening bridges are not addressed. Much of the discussion that follows also applies to new bridges constructed in stages, part width at a time.

CHAPTER 2—DEFINITIONS

2.1—Definitions

ACI provides a comprehensive list of definitions through an online resource, “ACI Concrete Terminology,” <http://terminology.concrete.org>.

CHAPTER 3—GENERAL DESIGN CONSIDERATIONS

3.1—General

Certain aspects of structural type selection, framing considerations, and design details are unique to bridge widening. AASHTO (2010) and others (Silano et al. 1992) provide specific design guidelines. Questions a design professional should consider before commencing design include:

- a) By widening the superstructure, does the substructure also require widening?
- b) Was widening the substructure foreseen in the design of the existing bridge?
- c) Should one or both sides be widened?
- d) Is a parallel structure justified as an alternative to widening?
- e) Does widening the structure provide adequate vertical clearance?
- f) Have geotechnical/ground conditions been evaluated?
- g) Does widening provide an acceptable life for the existing section?

In general, current bridge codes and design loads applicable to the route on which the structure is located should be used for bridge widening. Constructing a widening to current standards creates the opportunity of later replacing or strengthening all or portions of the original bridge so that the entire structure can be upgraded.

Bridges to be constructed for special purposes (for example, military bridges) may require higher design loads than standard truck loads shown in AASHTO (2013) due to heavier traffic loads, a lack of load limits, or a lack of enforcement of load limits. Specific structural considerations may be necessary for widening a bridge in seismic regions; for example,



Fig. 3.2.1a—Concrete arch widening with prestressed sections.

to avoid a possible progressive collapse of a bridge during a seismic event (Asnaashari et al. 2005), precast concrete girders can be spliced together.

3.2—Appearance and function

When a bridge structure is selected for widening, factors such as aesthetic and historical considerations, roadway geometrics, and maintenance of traffic should be considered.

3.2.1 Aesthetic and historic considerations—Aesthetic and historic factors can favor maintaining the original appearance of a classical design or landmark structure. Figure 3.2.1a shows open-spandrel concrete arches that have been widened with thin prestressed members matching the depth of the original superstructure. The prestressed members actually carry the entire bridge deck loads, and the arches were left in place to maintain the appearance of the historic bridge. A bridge widening design can sometimes require different structural types when compared to the existing bridge. For example, the arch-shaped steel truss bridge over Auckland Harbor in New Zealand was widened with steel box girders outside the truss on both sides, the soffits of which matched the curve of the original lower chords (Fig. 3.2.1b). To all but the most astute viewer, the architectural integrity of the original design was not altered.

The widening should be accomplished in a manner such that the existing structure retains its original aesthetic outlook.

3.2.2 Roadway geometrics—If the widening consists of doubling the bridge width (for example, two to four lanes divided), the work is generally much less complicated and less costly when the widening is done entirely on one side. The widening can be built as an independent bridge without the problems of making closure placements or matching deflection characteristics. Traffic handling during construction is also simplified. When vertical clearances beneath separation structures are insufficient to allow for falsework during bridge widening, the use of precast concrete or steel girders is generally required. The widened portion must provide adequate vertical clearance both before and after construction.

3.2.3 Maintenance of traffic—Prime concerns of widening are the convenience of the traveling public, the safety of



Fig. 3.2.1b—Widened bridge with steel box girders, Auckland Harbor in New Zealand.



Fig. 3.2.3—Traffic allowed on a bridge during deck slab widening.

construction personnel, and the potential damage to the work. Another consideration is the effect of the widening on the safety of the public using the roadway, waterway, or railway beneath the bridge and any traffic-related impact that the widening can have on that roadway. Ideally, a convenient alternate route should be used as a detour during bridge-widening operations, so that all traffic can be kept off the bridge. More commonly, however, the high cost of a temporary detour bridge dictates that traffic be carried on the bridge during widening, as shown in Fig. 3.2.3. This may create congestion at the work site and result in vibrations and deflections of the bridge (Whiffen and Leonard 1971; Arnold 1980; Furr and Fouad 1981; Transportation Research Board 1981; Deaver 1982; Silfwerbrand 1992; Harsh and Darwin 1983).

When a detour is not feasible and traffic must be carried through the work area, proper sequencing of construction operations is essential to minimize these problems. It is normally preferable to do as much of the work as possible before the removal of existing curb and railing. Sometimes it is possible to complete the entire widening before removing the existing rails, including making the connection between old and new bridge decks. Otherwise, temporary barriers or railings must be provided after the existing curb and rails have been removed.

The U.S. Department of Transportation (2009) details the minimum traffic control standards for construction and maintenance operations on streets and highways. This manual sets forth principles and standards that apply to both rural and urban areas and is intended to direct the safe and expeditious movement of traffic through construction and maintenance zones and provide for the safety of the work force. In addition to the requirements of this manual, supplementary protection may be requested by the owner.

The following should be indicated in the contract documents: the sequence of construction operations, permissible lane closure periods, minimum temporary roadway widths, temporary traffic striping requirements, signing layouts, locations and details of temporary barrier railings, and minimum construction openings for roadways or railways under the bridge. Contractors should be encouraged to propose alternative schemes.

When high volumes of traffic need to be carried on a bridge in which both sides are to be widened, it may be necessary to complete one side before the other is started to minimize disruption of traffic.

When heavy volumes of commuter traffic prevent closing the existing bridge lanes except during brief off-peak periods each day, special measures may be needed (Precast/Prestressed Concrete Institute 1980; Sprinkel 1985). For example, precast bridge deck slabs and concrete-filled steel grating can be placed during nighttime or weekend closures.

3.3—Differential movement

Deflection characteristics and differential expansion behavior should be considered when a new deck is added or connected to existing decks.

3.3.1 Vibrations from traffic—Traffic-induced vibration has been blamed for distress occasionally observed in new construction that connects to structures carrying live loads. Once concrete is placed, consolidated, and finished, it generally should not be disturbed until it has gained sufficient initial strength. For example, over 65 percent of a specified compressive strength may be achieved after 7 days of casting when a concrete is mixed with ordinary portland cement (Gonnerman and Lerch 1951). This requirement leads to concerns about permitting traffic on bridge decks during concrete-placing operations. Experience and research have shown, however, that damage due to traffic-induced vibrations is very rare when the forms and reinforcing steel are supported by the same structural members (Whiffen and Leonard 1971; Arnold 1980; Furr and Fouad 1981; Transportation Research Board 1981; Deaver 1982; Harsh and Darwin 1983; Silfwerbrand 1992). In these cases, fresh concrete, reinforcement, and forms are in synchronous movement. None of these reports were able to identify any occurrences of damage for these conditions. Therefore, special precautions, such as closing the bridge to traffic in such situations, are generally not necessary even though vibrations may cause some minor cracks during the curing of concrete members (Ng and Kwan 2007).

Effective ways to reduce the amplitude of traffic-induced vibrations are to maintain a smooth structure approach and

bridge deck riding surface as well as increasing member stiffness. Vehicle speed and weight restrictions may not be a critical issue for the magnitude of traffic-induced vibrations (Kim et al. 2009).

In situations where the vibrations are carried into freshly placed concrete through reinforcing steel extending from the existing bridge, damage to new concrete may occur (Silfwerbrand 1992). Adequate construction methods can preclude such damage, for example, by attaching the forms to the existing bridge, with proper traffic control, or both.

When a reinforcing bar moves relative to the concrete, the displaced concrete will flow readily back and forth with the bar because it is still in its plastic state. As initial set begins, only weak, water-diluted grout flows back to surround the bar. Also, cracks may develop in the plastic concrete and fill with weak material along a horizontal plane with adjacent bars or along sloping planes running from the bar to the surface of the bridge deck. This condition can result in a severe reduction in bond to reinforcement and premature bridge deck spalling. Similar damage can occur in new bridge decks if live loads from workers or equipment are allowed directly on poorly supported reinforcing steel on the outside of a construction joint bulkhead. For this reason, during placing and finishing operations, workers and equipment near the perimeter of a reinforced concrete bridge deck should be restricted to planks or runways supported from the forms, rather than bearing directly on any reinforcing steel that extends through bulkheads and into the concrete being placed.

Although it would seem that any movement of reinforcing steel extending from a structure carrying traffic into freshly placed concrete would result in the defects described, certain practices will generally eliminate such damage. These practices should be employed on all bridge deck closure placements or in other situations where concrete is placed against an existing structural element carrying traffic, and include the following.

3.3.1.1 Use of moderate-slump concrete (2 to 3 in. [50 to 75 mm])—Surveys found frequent delamination in bridge decks built or widened in the 1950s and 1960s (Transportation Research Board 1981). This damage was noted in bridge decks connecting to existing structures carrying traffic. Such damage was attributed to the use of high-slump concrete (more than 4 in. [100 mm]) that probably contained excess water. Laboratory research also showed that high-slump concrete mixtures are especially sensitive to segregation in the plane of the reinforcing steel (Arnold 1980). Similar damage was not noticed when the slump was reduced.

3.3.1.2 Reinforcing details—Furr and Fouad (1981) reported that reinforcing dowels extending straight from old concrete and lapping with the new bridge deck reinforcing bars in fresh concrete did not cause any defects in the fresh concrete. Splicing dowel bars to existing reinforcement may be necessary for cantilever slabs.

Good practice also requires that when bridge deck closure placements are to be employed, the reinforcing bars or dowels extending from the existing concrete to the new concrete should not be connected to the reinforcing bars in the closure placement during concrete placement. They should