Chapter 4: Loads

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4-1 Introduction

The number one goal of an engineering plan to remove a bridge, or an element of a bridge, is to do it safely. The other goals of protecting worker health, property, and environmental resources cannot be achieved if the bridge removal is not performed in a controlled and predictable manner. The bridge removal work plan must consider the overall stability of the entire structure and the individual capacity of local supporting elements. A fundamental part of the bridge removal work plan is the removal sequence and necessary staging that is part of the plan. It is only possible to evaluate the stability and capacity if the sequence of removal is well defined, including the placement of equipment on the structure.

The need for possible temporary supports, temporary covers, or lateral bracing can be evaluated with a well-defined removal sequence.

The use of protective covers to control debris requires consideration of the impact falling debris has on such a cover. The *Contract Specifications*, Section 60-2.01C, *Existing Structures – Structure Removal – General – Construction,* requires that the minimum protective cover be equivalent to 2-inch Douglas-fir planking on posts spaced at 5-foot centers. This specification anticipates a typical situation where concrete debris is dislodged from an element like a deck slab. Because the concrete is rattled out from closely spaced rebar and is falling a modest height, experience has demonstrated that this type of prescriptive cover is adequate.

4-2 General Loading Requirements

The basic requirement for temporary supports, temporary covers, and temporary lateral bracing is that they must resist the sum of all loads imposed.

Temporary supports and temporary covers for bridge removal are designed under the *Contract Specifications*, Section 48, *Temporary Structures*. The minimum vertical loads are consistent with the requirements for new falsework construction. The minimum horizontal loading for wind is likewise consistent with new falsework construction. However, the minimum horizontal loading requirement found in the *Contract Specifications*, Section 48-3.02B, *Temporary Structures – Temporary Supports – Materials – Design Criteria*, is the force as specified, plus an allowance for wind but not less than a percentage of the total dead load of the structure being removed as described in Section 4-5, *Horizontal Loads.*

4-3 Dead Loads

Dead loads include the weight of all concrete, bar reinforcement, and self-weight of the temporary structure. The minimum dead load for normal weight concrete and rebar is 160 pcf, which is reduced to 130 pcf for lightweight concrete. The concrete dead load generally includes the weight of concrete material, forms, and bar reinforcement. Site specific evaluation may be necessary to determine if the weight of forms will be included in the dead load calculation or if it is calculated separately. If calculated separately, then the dead load of concrete is to be not less than 150 pcf for normal weight concrete and 120 pcf for lightweight concrete. See Figure 4-1 for an illustration of a bridge typical section, used to calculate concrete dead load.

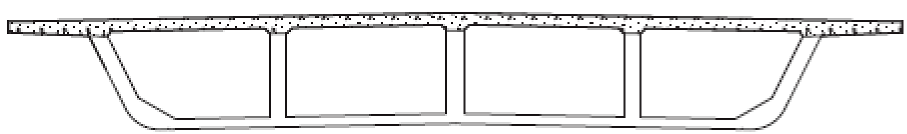

Figure 4-1. Typical Box Girder Cross-Section (Dead Load)

4-4 Live Loads

Any temporary structure needs to support the actual live load, including all equipment to be supported during the bridge removal such as excavators and loaders, with a minimum uniform live load of not less than 20 psf. See Figure 4-2 for an illustration of live load due to equipment.

Cal/OSHA *Construction Safety Orders (CSO)*, § 1717, *Falsework and Vertical Shoring*, requires a minimum of 100 psf for vertical shoring supporting concrete and Cal/OSHA *CSO*, § 1637, *General Requirements,* requires that the walkway (scaffold) support four times the maximum live load plus self-weight of the structure without failure (i.e., ultimate load). Note that the *CSO* is found in the California Code of Regulations (CCR) Title 8, Division 1, Chapter 4, Subchapter 4.

Figure 4-2. Typical Equipment Live Load, Carpinteria Creek

4-5 Horizontal Loads

The minimum horizontal wind loading is consistent with new falsework construction. The minimum wind load is specified in the *Contract Specifications*, Section 48-3.02B, *Temporary Structures – Temporary Supports – Materials – Design Criteria*.

The minimum horizontal loading requirement found in the *Contract Specifications*, Section 48-3.02B, *Temporary Structures – Temporary Supports – Materials – Design Criteria*, is the force as described and an allowance for wind but not less than

5 to 10 percent of the total dead load of the structure being removed (refer to the project specific contract documents for the applicable minimum percentage). This minimum horizontal loading is increased from the standard 2 percent for new construction to 5 percent for bridge removal because of the greater uncertainties involved.

Operating equipment on a structure can impart significant horizontal loads to the resisting elements of the structure. For example, dynamic forces like wheel braking from a vehicle or construction equipment get transferred to the structure as a horizontal load. Also, an excavator boom can exert horizontal forces that approach the dead weight of a vehicle.

4-6 Removal Sequence

As most structures are not perfectly symmetrical, beginning bridge removal from one abutment and proceeding to the other abutment is not the equivalent of the reverse order of construction. There must be an agreement as to the abutment and bent numbering for a written sequence to be valid. It is not common, but some older bridges have had their bents numbered inconsistently from one contract to another. If working from the as-built project plans, it is essential to verify that the bents are numbered in the same manner as the contract and bridge removal work plans indicate.

The *Contract Specifications*, Section 60-2.02C(3), *Existing Structures – Structure Removal – Bridge Removal – Construction – Preliminary Work*, defines the nature of preliminary work. The bridge removal work plan should detail the sequence of work sufficiently to remove any ambiguity of what is considered preliminary work as authorized by the Engineer.

While the removal sequence is essential in evaluating the structural stability of the remaining structure, it is also important in scheduling lane closures, railroad flaggers, and other auxiliary work requirements. When a successful bridge removal operation is dependent on time of completion, the steps in the removal sequence should have a duration allocated to them so that adjustments can be made in the allocation of resources if the schedule lags.

4-7 Stability

The *Contract Specifications,* Section 60-2, *Existing Structures – Structure Removal*, requires that the structure remain stable during each stage of removal. The *Contract Specifications* also require that calculations must be submitted, demonstrating stability for each stage.

The details in the as-built project plans are essential in the planning stages of removal and evaluating stability. Whether columns are assumed fixed or pinned is partially dependent on the original design but also on the actual conditions at the time of removal. Due to scour and erosion of the riverbed, the piles may be exposed. Even if the footing has been shored up with riprap, the piles may have issues with corrosion because of exposure to the atmosphere. Because a compromised foundation may not be able to resist any significant moments during removal operations, the actual condition needs to be evaluated carefully at each site. Even in an arid site, there may be hidden or unknown conditions that have led to deterioration of bridge components; thus, actual conditions must be investigated at all sites.

Figure 4-3. Temporary Support During Partial Removal and Bridge Raising, Oroville

Occasionally the proposed bridge removal work plan includes the use of equipment to provide temporary stability. An excavator or other similar equipment could be used as a simple dead weight to stabilize an element like a girder or a column. If the stability plan requires active participation from an equipment operator to be successful, the complexity increases by an order of magnitude. Is the operator able to see and hear well enough to be effective or is the operator relying upon direction from a spotter? Crane operators often work in cooperation with a certified signal person, but an equipment operator may not be as experienced in receiving critical direction from third parties, especially in noisy environments where the line of sight is impaired. Careful planning, clear lines of authority and direction, and preparation are required when active participation from equipment is part of the bridge removal work plan.

Precast girders and steel girders are not usually stable as stand-alone individual components. During bridge construction, these elements often require temporary lateral support until the diaphragms are installed. Some steel girders may have been erected in pairs with the diaphragms preinstalled; a removal sequence may benefit from a similar strategy. Since the bridge deck provides considerable stability to individual girders, removing or compromising the integrity of the bridge deck as part of the removal sequence requires evaluation of stability. Girders with a horizontal radius between bents can become globally unstable as the deck is removed. Girders and diaphragms can be damaged during removal operations. The intermediate diaphragms in steel girder bridges can suffer fatigue cracking during their years of service which would compromise their ability to provide stability during removal. Inspection of existing and developing conditions is essential in planning and executing a bridge removal. Knowing that steel girders are sensitive to damage, the integrity of the compression flange is a concern. Bridge deck removal by hydraulic breaker sometimes exposes the top flange to damage. When the top flange in compression gets bent and is no longer restrained by the deck, buckling can occur which could lead to collapse. A better option is to clearly mark girder locations and use a more controlled removal method near the girder.

Prestressed elements have energy stored in the tendons. Most prestressed elements have tendons that are grouted and fully bonded to the structure and there is little danger of damage to the anchorage. There are exceptions; unbonded tendons can release almost explosive energy when an anchorage is removed. This is a good reason to review the as-built project plans and proceed with caution during bridge removal. There are some structures that have auxiliary tendons installed in conduits beside the original girders. The grouted conduits are relatively slender compared to the stored energy and cutting the tendon from the girder might cause it to suddenly bend out of plane.

Removal of the bridge deck from a post-tensioned structure can damage the girders, as the bridge was originally post-tensioned after deck installation, and the deck acts an integral top flange. The removal of the deck dead weight can unbalance post-tension forces, causing deflection and associated cracks in the girders.

Removing girders with a crane is common over water or areas with difficult access. A crane on a barge has additional operational concerns as a barge can pitch and roll with loading. The capacity of a crane operating from a barge should be downrated because of uncertainties. Crane manufactures can require up to 50 percent reduced maximum capacity when operation is from a barge. Removing girders with two crane picks increases the complexity and introduces communication issues, and again because of uncertainties the maximum capacity of the cranes should be downrated. Cal/OSHA *CSO*, § 1616.7, *Multiple-Crane/Derrick Lifts – Supplemental Requirements,* requires a qualified person other than the operators to direct the operations and generally requires a minimum 25 percent reduction in crane capacity for two crane picks. Successful removal of existing girders by crane is dependent on many details such as wind and weather, rigging, supporting mats and pads, engineering assumptions, and site management, as well as operational communications. Once the girder is landed off the structure, there continue to be stability and hazardous material issues as it is processed and removed from the site.

See Figure 4-3 for an illustration of a unique situation where temporary supports were used to facilitate both partial removal and bridge raising. See Figure 4-4 for an illustration of a precast girder being removed with an excavator.

Figure 4-4. Precast Girder Removal with Excavator, Hat Creek