Chapter 3: Bridge Removal Methods

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3-1 Introduction

Bridge removal can be divided into the following two general categories: partial removal and complete removal. The *Contract Specifications*, Section 60, *Existing Structures,* and Section 15, *Existing Facilities,* work in tandem to describe the bridge removal in general and places limits on the means and methods to be employed. In all situations, it is required that the best general practices are to be used. Note that when the *Contract Specifications* are referenced in a general sense throughout this chapter, it is referring to Section 60-2.01C, *Existing Structures – Structure Removal – General – Construction*.

The Contractor is contractually obligated to provide for the safety and convenience of the public during all stages of bridge removal. The Department has considered the needs of the travelling public and has prioritized safe transit through or around our projects for pedestrians, including the disabled. Communication of closures and construction duration helps with community support and acceptance.

Safety is always the number one objective. If an operation cannot be done safely, then it should not proceed. Expediency and economic considerations are never to take priority over safety when removing a bridge.

3-2 Bridge Removal Types

As stated in the introduction, bridge removal generally falls into two categories in the scope of the work performed by Caltrans: partial bridge removal and complete bridge removal. Partial bridge removal is the most common type of bridge removal encountered on Caltrans projects and can vary from concrete barrier rail removal to removal of lacing from steel truss bridges and everything in between. Similarly, complete bridge removal can vary from a single span concrete box girder to a multi-span cantilever steel truss bridge.

The focus of this manual is to provide a reference and resource for the most common bridge removal types at Caltrans – partial and complete bridge removal of concrete and steel girder structures. There are many other types of structures and methods such as cantilever steel trusses or explosive demolition that are relatively uncommon and will not be discussed in detail, with only an overview provided in sections 3-7.01 and 3-5.11, respectively.

Appendix A, *Removing Concrete from Bridges NCHRP 169*, is a useful reference prepared by the Transportation Research Board – National Cooperative Highway Research Program. The following sections of this chapter discuss bridge removal in detail, including typical equipment, temporary supports, and special locations.

3-3 Partial Bridge Removal

Partial removal of bridge elements is incidental to many rehabilitation or widening projects.

Typical partial removal situations include:

1. Rail replacement
2. Widenings
3. Joint seal replacement and repair
4. Complete deck replacement
5. Deck surface replacement
6. Bent replacement
7. Seismic retrofit
8. Installation of access openings
9. Hinge repair or replacement

Whenever partial removal of a monolithic concrete element is required, and limiting the spalling of concrete that is to remain in place is desired, a limited depth saw cut is necessary. The *Contract Specifications* require a 1-inch-deep saw cut when the joint line will be visible in the finished work. The limited depth saw cut is also used to preserve reinforcing steel, a common component of bridge widening projects. Where both sides of an element are going to be visible, a saw cut is required on both surfaces; a common example is where the overhang of a deck is partially removed for a widening. In some cases, a full 1-inch-deep saw cut may be in conflict with the need to preserve existing embedded steel reinforcement; in such situations, good engineering judgment should prevail.

The *Contract Specifications* limit the means and methods of any partial removal of an element supported by a bridge. The intent is to protect the structure to remain in place. No free-falling mass, or a mass attached to a cable such as a ball-and-crane, is permitted because it is too difficult to control. No hammer with a manufacturer's rated striking energy greater than 1,200 ft-lb per blow is permitted. These specific equipment prohibitions alone do not ensure that the existing structure will not be damaged. Other factors that can damage the existing structure are operational frequency of the impact hammer, tool tips used to break concrete, skill of operator, and duration of breaking operation.

Operator skill is an important element to a successful partial removal. For instance, the operator might have to adjust their angle of attack, tool point, or work rate. A skilled demolition operator is not developed overnight. It can take years for an operator to become familiar with the equipment and the many demolition situations encountered. Tractor mounted hydraulic hammer breakers have a variety of tools available; an efficient moil point might be swapped out for a chisel or blunt tool to limit damage. Hammers, as mechanical devices, eventually wear out and require maintenance to function satisfactorily and in a controllable manner. Some manufacturers are producing hydraulic breakers that can automatically vary the frequency and energy of the tool impact for improved efficiency and results. When detail work is required or where appropriate, handheld pneumatic hammers are used on bridge removal projects.

Partial removal operations require monitoring to limit damage to the portion of the bridge that stays in place. Besides the general contractual requirement that the process be supervised as well as monitored by the Contractor's engineer, the State's field engineer should intercede if unintended damage is occurring. In almost all cases, it is more cost efficient to limit unintended damage than to make corrective repairs after the fact.

3-4 Complete Bridge Removal

Complete bridge removal is required when a structure is abandoned or replaced. Sometimes staged removal and construction is required where traffic is shifted to reduced lanes (number and/or width) while a portion of the bridge is removed, and a portion of the new structure is built.

Complete bridge removal methods and sequencing is dependent upon the structure type and materials. For structures that are not too tall, all the demolition equipment can be positioned on the ground, and removal can proceed relatively safely without concern for falling debris. The situation becomes more complex if the demolition equipment is operated from the bridge deck, as in the case of tall bridges and bridges over water, or if falling debris is a hazard to traffic, existing facilities, or the environment.

Complete bridge removal with workers and equipment on the structure must consider and ensure that there is adequate structural stability of the remaining structure during all intermediate demolition stages.

Generally, the *Contract Specifications* develop over time to meet the objectives and intent of similar work. Historically, unfortunate bridge demolition incidents have directly resulted in the development of bridge removal *Contract Specifications* and guidance. Well-developed *Contract Specifications* combined with experience and cautious engineering judgement are required to administer a bridge removal contract.

3-5 Typical Equipment

3-5.01 Excavator

The excavator is the workhorse of most modern bridge removal projects encountered on State highway bridges. The modern excavator is a versatile piece of machinery that has made it one of the most popular tools for bridge removal. Often, the bridge removal site has several excavators at work. Excavators come in a wide range of sizes and configurations, from mini-excavators to long reach excavators. The size and resultant high self-weight of the excavator become a concern when operating from a bridge deck or temporary structure. The excavator can exert large lateral loads when operating on a structure. With the wide range of implements, from percussive hammers to hydraulic-operated crushers, the excavator is used for everything from initial breaking of the deck to loading out trucks. See Figures 3-1 through 3-4, for photos of excavators.

Common excavator attachments used in bridge removal work are:

1. Hydraulic breaker
2. Bucket with thumb
3. Metal shear
4. Rock crusher.

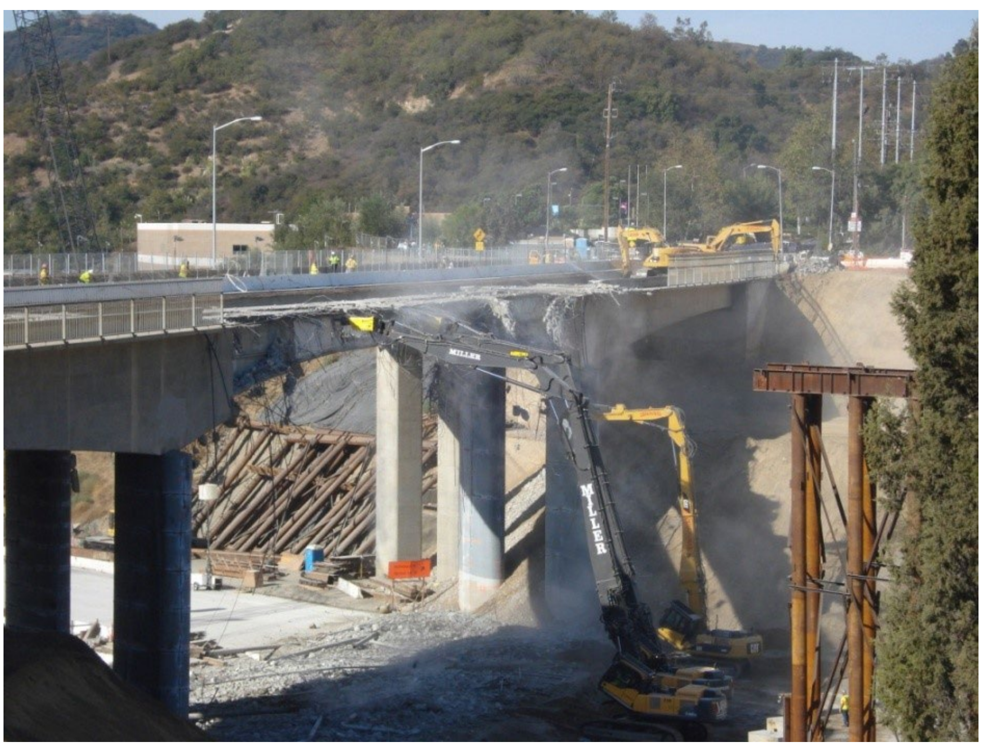

Figure 3-1. Long Reach Excavator at Mulholland Drive, Los Angeles

Figure 3-2. Excavator Ballet at Doyle Drive, San Francisco

Figure 3-3. Excavator Removing Control House, Potato Slough

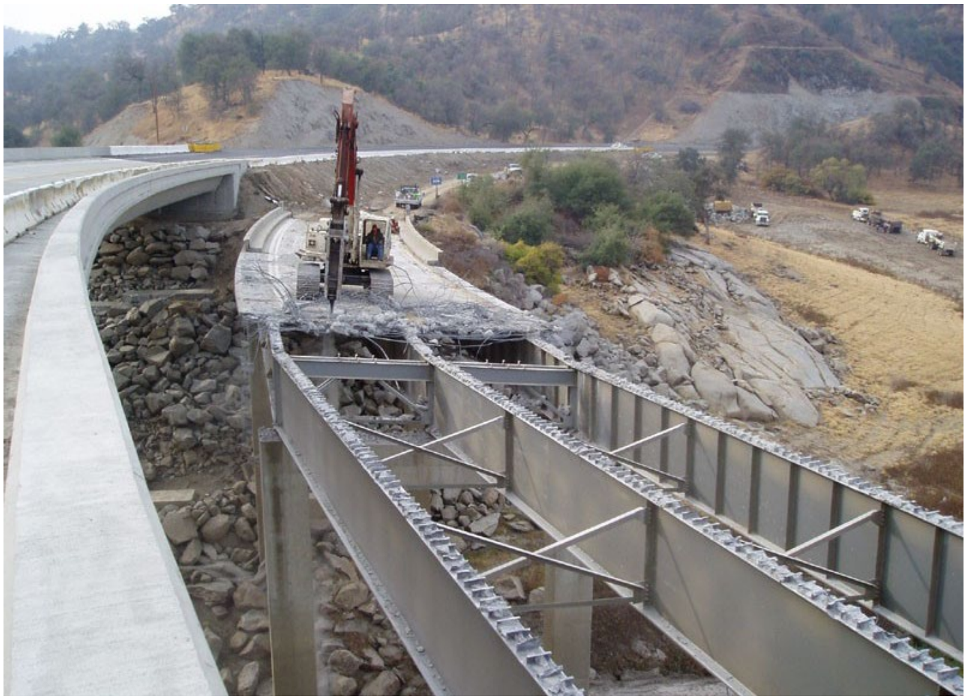

Figure 3-4. Excavator Removing Concrete Deck on Steel Girders

3-5.02 Loader

The loader is most often used during bridge demolition for material handling in removing debris and loading trucks. On occasion, the loader may be used to apply a lateral force to topple or stabilize a bridge element. See Figure 3-5 for a photo of a loader.

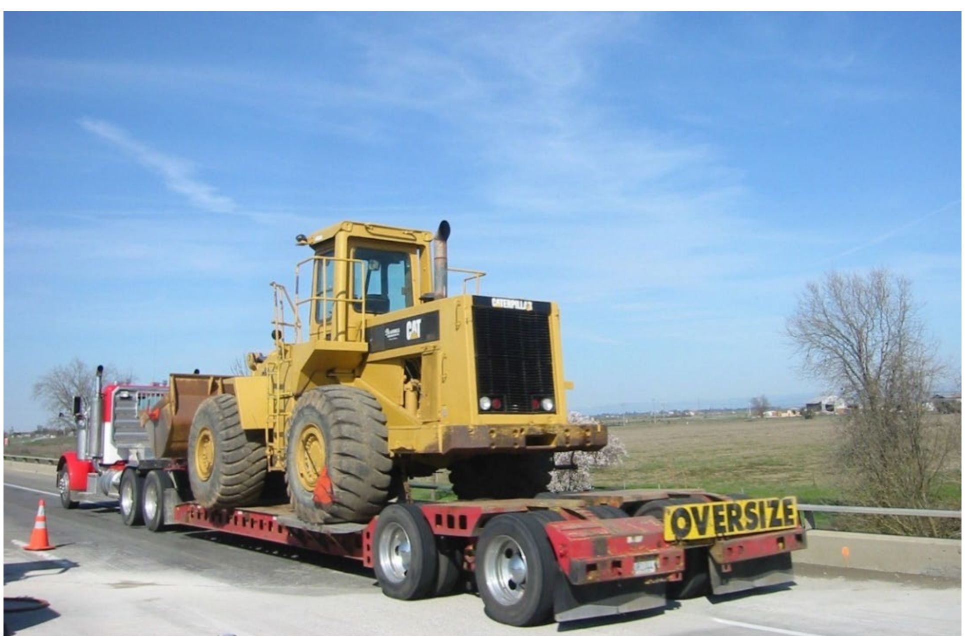

Figure 3-5. Loader on a Low-Boy Trailer

3-5.03 Concrete Saws

Concrete saws are an essential tool used in bridge removal, bridge rehabilitation, or anywhere a portion of the structure is to remain intact. The common types of concrete saws used in bridge removal are:

1. Circular water cooled (see Figure 3-6)
2. Diamond wire saw (refer to section 3-5.04 for a more in-depth discussion)
3. Small handheld dry cut.

Concrete saws do have some hazards that warrant attention. Most concrete saws generate slurry during the cutting operation, which can be hazardous to aquatic life and can become an airborne hazard when dry. Concrete saws, including water-cooled models, can generate sparks that may pose a fire hazard in some environments.

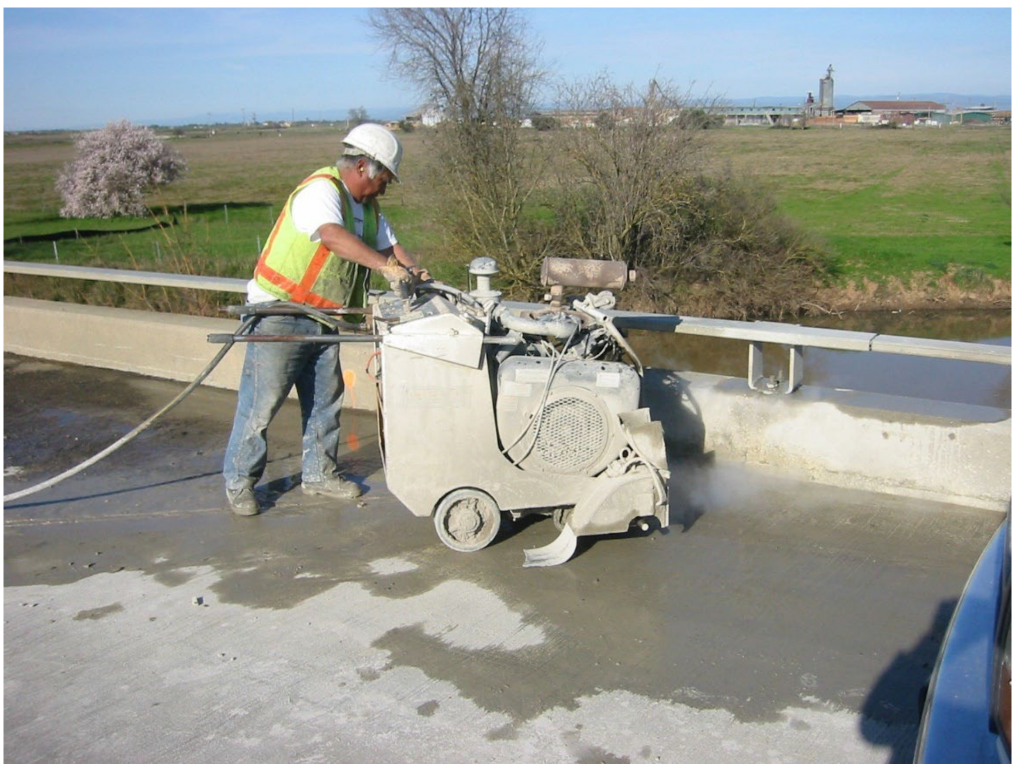

Figure 3-6. Water Cooled Concrete Saw

3-5.04 Diamond Wire Saws

The diamond wire saw is almost unlimited, dimension wise, in its ability to cut reinforced concrete structural elements. It has been very successful in underwater cutting of larger pier structures, or in cutting bent caps or other elements that need to remain intact. See Figures 3-7 and 3-8 for photos of diamond wire saws.

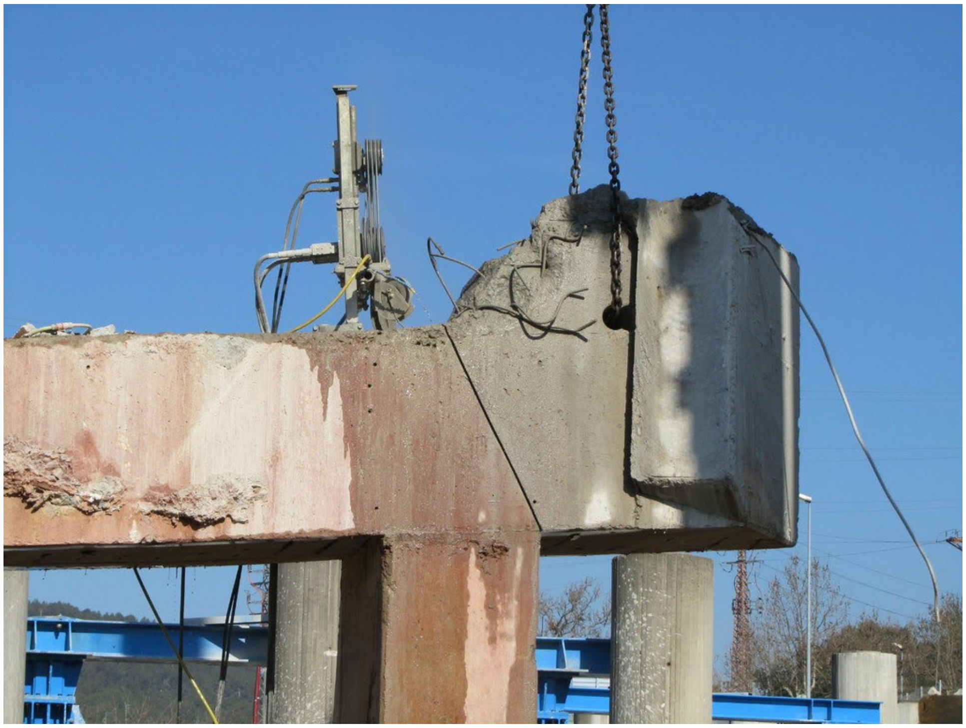

Figure 3-7. Diamond Wire Saw

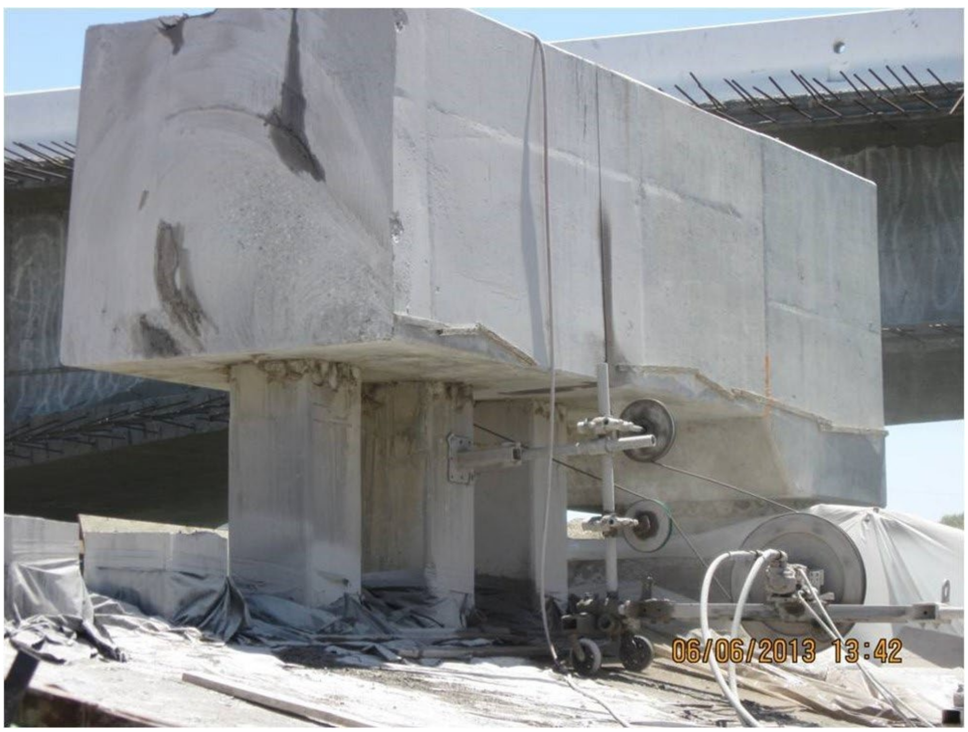

Figure 3-8. Diamond Wire Saw, Colorado River

3-5.05 Pneumatic Hammers

Pneumatic handheld hammers (illustrated in Figure 3-9), come in many sizes; everything from rivet busters to jackhammers. Handheld hammers are most frequently employed where access or demolition control is an issue. The operator is in close proximity to the work which affords adjustments to the operation to prevent unwanted damage. There is a wide range of bits available, including moil points, chisels, and bushing heads. Pneumatic hammers require a high-capacity air compressor. The air supply lines are vulnerable to damage and wear and require frequent inspection and coupler restraints.

Figure 3-9. Handheld Pneumatic Hammer, Bear River

3-5.06 Drills

Drills are used for any location where a hole is required. Examples include a place to thread a diamond wire cable, installing a pick hole, or preceding the installation of expansive chemicals. Drills come in many configurations; of particular note for bridge removal is the impact or hammer drill which can be very efficient. Core drilling through concrete with water cooling generates slurry which needs to be contained to protect aquatic life and to conform with Storm Water Pollution Prevention Program (SWPPP) requirements.

3-5.07 Flame Cutting

The primary methods of flame cutting encountered in bridge removal are:

1. Oxyacetylene torch (see Figures 3-10 and 3-11)
2. Air carbon arc cutting
3. Magnesium torch used in underwater cutting.

These tools are essential for cutting structural steel and bar reinforcement. Lead abatement is usually required if the steel has a lead-based coating. Handheld torches are usually employed in bridge removal work, producing fumes and hot slag as typical hazards. The transportation and storage of gas cylinders are also safety concerns. Personal protective equipment is required, and in some areas, fire protection is required.

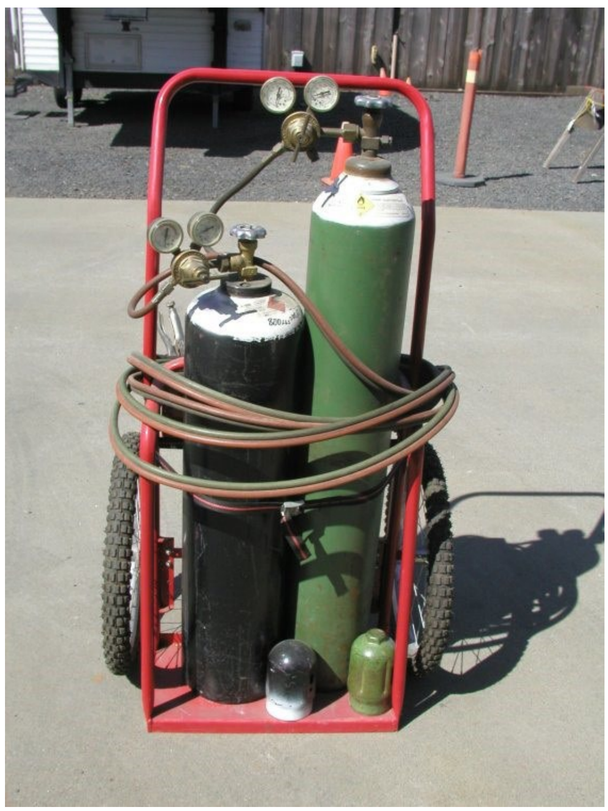

Figure 3-10. Oxyacetylene Torch Setup

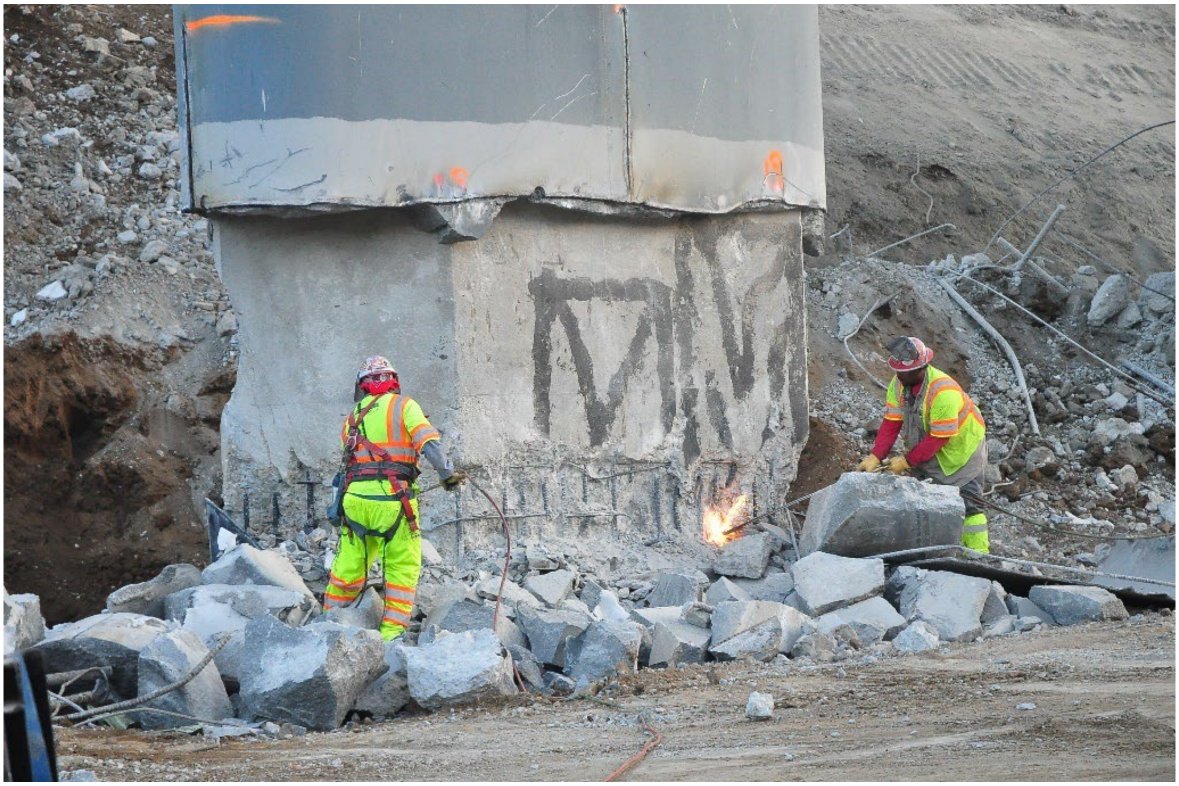

Figure 3-11. Torches Removing Column Reinforcement, Mulholland Drive, Los Angeles

3-5.08 Expansive Chemicals

Expansive chemicals are generally mixed as a grout type mixture and placed in pre-drilled holes. The chemicals expand as they cure, breaking up the concrete. This method is less effective with highly reinforced concrete elements. Their advantage lies in that they work with minimal sound and vibration, compared to other methods.

3-5.09 Hydroblasting

Hydroblasting uses high pressure water to remove unsound concrete. It has the advantage of leaving a concrete surface and reinforcement well prepared for bonding. This method of bridge removal is well suited for removal of unsound concrete from a bridge deck. Hydroblasting produces fewer micro cracks in the remaining concrete when compared to typical impact hammer techniques. Hydroblasting has potential stormwater pollution implications that must be considered as well. See Figure 3-12 for an illustration of hydroblasting.

Figure 3-12. Hydroblasting for Partial Deck Removal

3-5.10 Free Falling Mass (Crane and Wrecking Ball)

The *Contract Specifications* prohibit the use of a free-falling mass (wrecking ball) as well as demolition by explosives. There are occasions where the contract *Special Provisions* allow for the use of one of these methods if they are deemed to be more effective than the standard bridge removal methods, or if there is an emergency situation. As such, these methods will be briefly mentioned.

Since the middle of the 20th century, the wrecking ball (illustrated in Figure 3-13) has been commonly used in the demolition of masonry and concrete structures. Recently, its use in the removal of bridges has diminished. This method has concerns for safety with a free-falling mass during bridge removal since the majority of bridge removal occurs near traffic or adjacent structures. Furthermore, this method is particularly ineffective and inefficient in removing modern reinforced concrete box girder bridges since they are highly reinforced, massive structures. More controllable and efficient means are available to contractors and, as previously mentioned, this method is prohibited by the *Contract Specifications.*

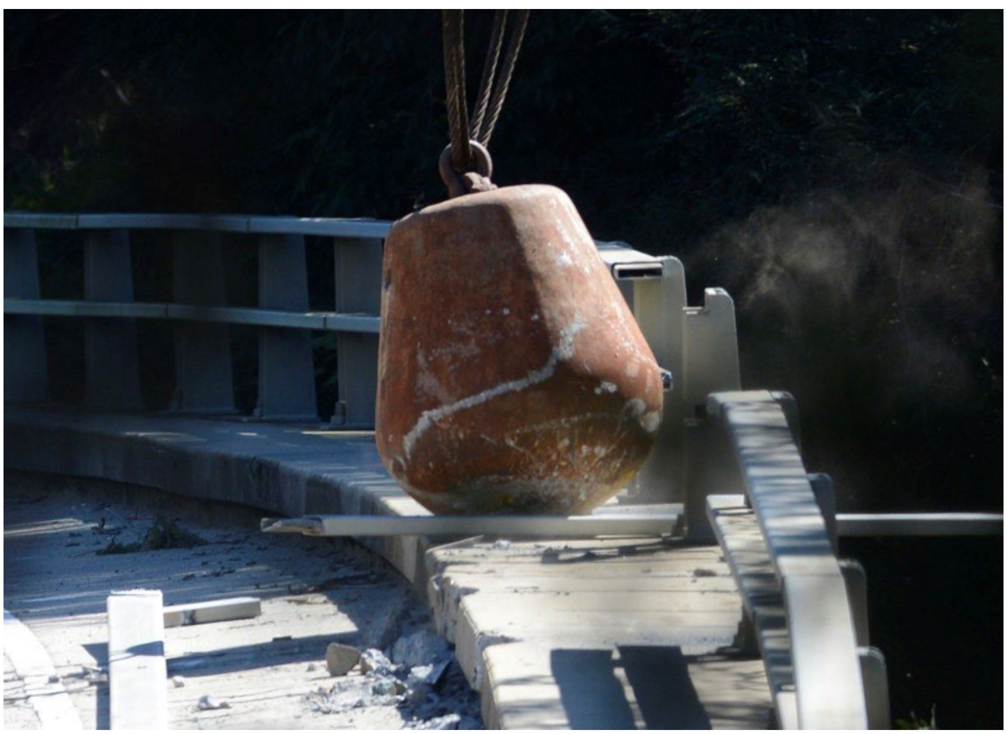

Figure 3-13. Wrecking Ball, Pfeiffer Canyon

3-5.11 Explosive Blasting

This method is rarely used or allowed by the *Special Provisions*. Blasting is prohibited by the *Contract Specifications* for reasons of safety and environmental concerns. However, there are situations where weighing the expediency and hazards make the option desirable. Blasting requires significant professional planning and experience in execution as well as multi-agency involvement. Blasting in maritime environments also requires significant mitigation measures such as bubble curtains to protect aquatic life as well as seismic and environmental monitoring.

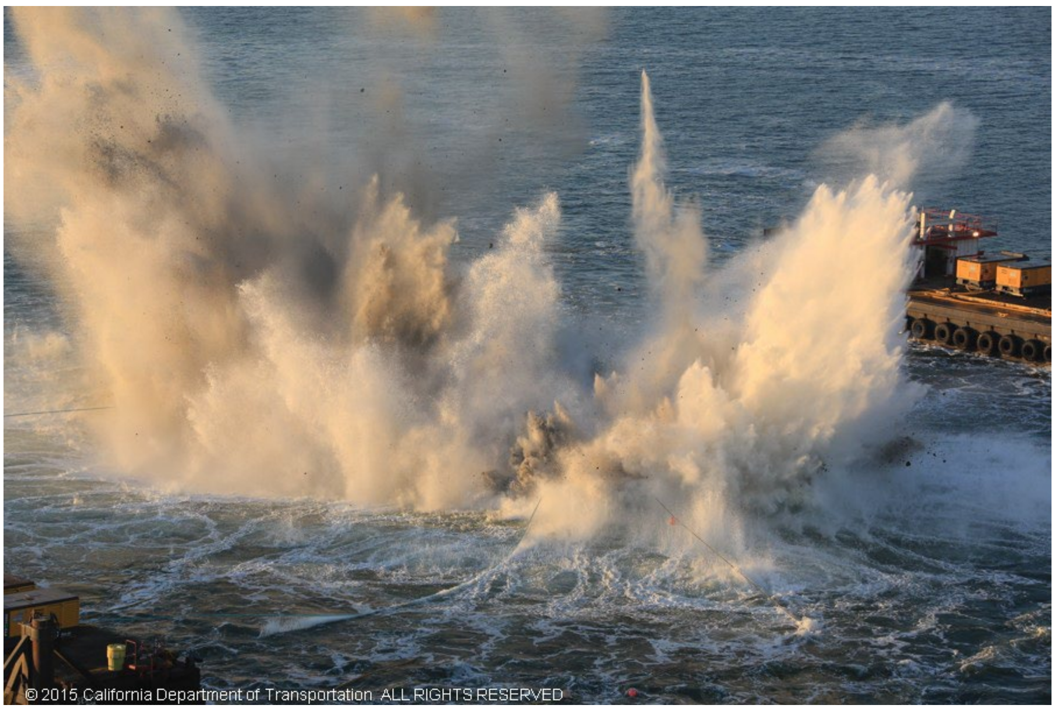

Figure 3-14. Explosive Demolition of a San Francisco-Oakland Bay Bridge Pier

3-6 Temporary Supports

Temporary supports are structural elements used to support existing structures during partial or complete bridge removal when necessary to support the bridge loads (dead, live, and lateral) while performing removal activities, as illustrated in Figure 3-15. Temporary supports are commonly used during hinge reconstruction and stage construction where bridge columns or abutments are pinned connections. See Figure 3-17 for an illustration of temporary supports at a hinge.

Commonly, temporary supports are designed similar to falsework and the *Falsework Manual* is used to analyze the structural elements. However, a major difference between falsework and temporary supports are the loads applied to the temporary structure. Typically, the vertical and horizontal loads for the temporary supports are shown on the contract plans for a particular location. On occasion, the Contractor may elect means and methods that use a temporary support that was not anticipated in the contract plans and for which loads are not provided. In these cases, the loads will need to be checked by the Structure Representative. The minimum horizontal load shall not be less than wind and 5 percent of the vertical dead load of the structure being removed per *Contract Specifications*, Section 48-3.02B, *Temporary Structures – Temporary Supports – Materials – Design Criteria*. The 5 percent is only a minimum and it may be higher depending on the site-specific conditions. The bridge design engineer should assist in developing loads in cases where live traffic will remain on the bridge.

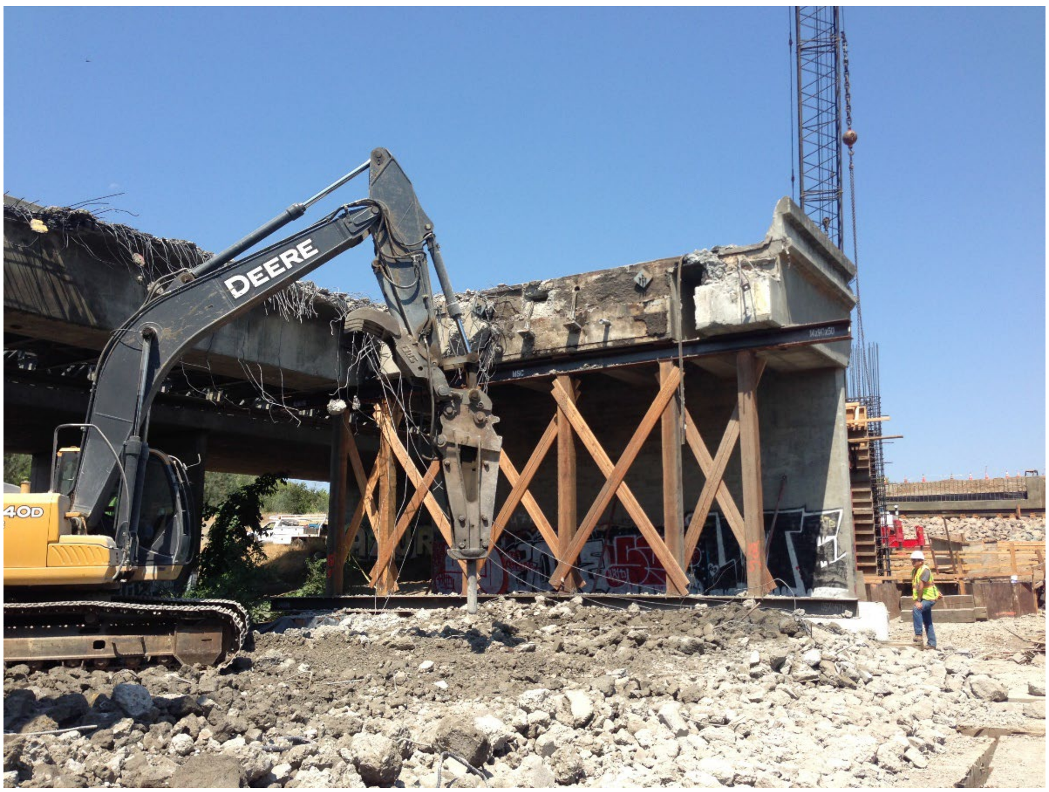

Figure 3-15. Temporary Support for Bridge Removal, Chico

Temporary supports are not always similar to falsework; they can be attached to existing structures as concrete or steel elements, they can be truss or suspended structures, or drilled or driven pile structures, among others. Figure 3-16 illustrates the use of a temporary support to suspend a portion of a compromised bridge. Temporary supports can also serve as multi-functional temporary structures in cases where the temporary support is also used as a protective cover or falsework; see Figure 3-17 for an illustration.

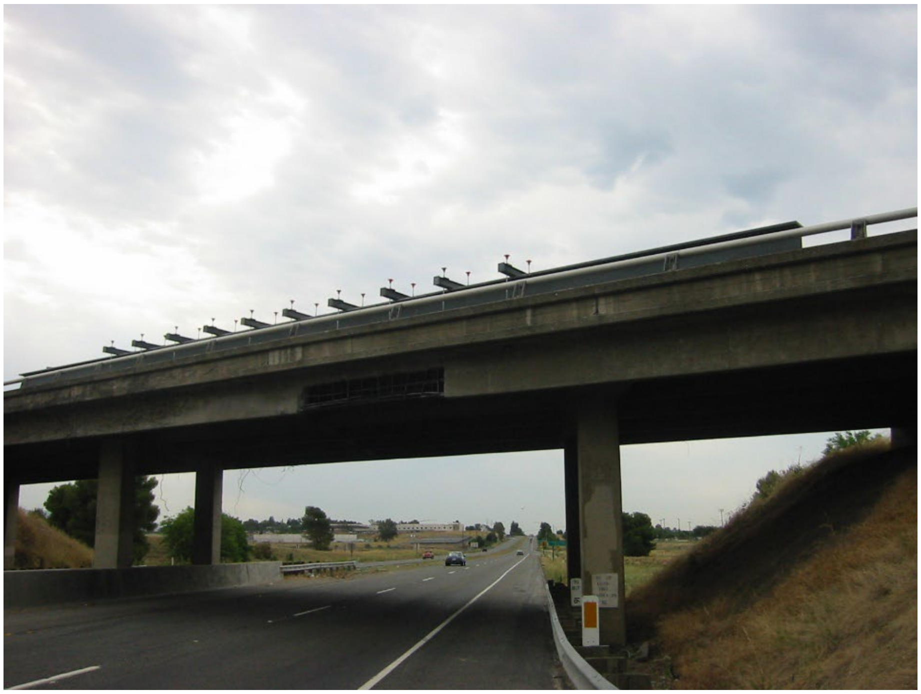

Figure 3-16. Piggy Back Beam, Oroville

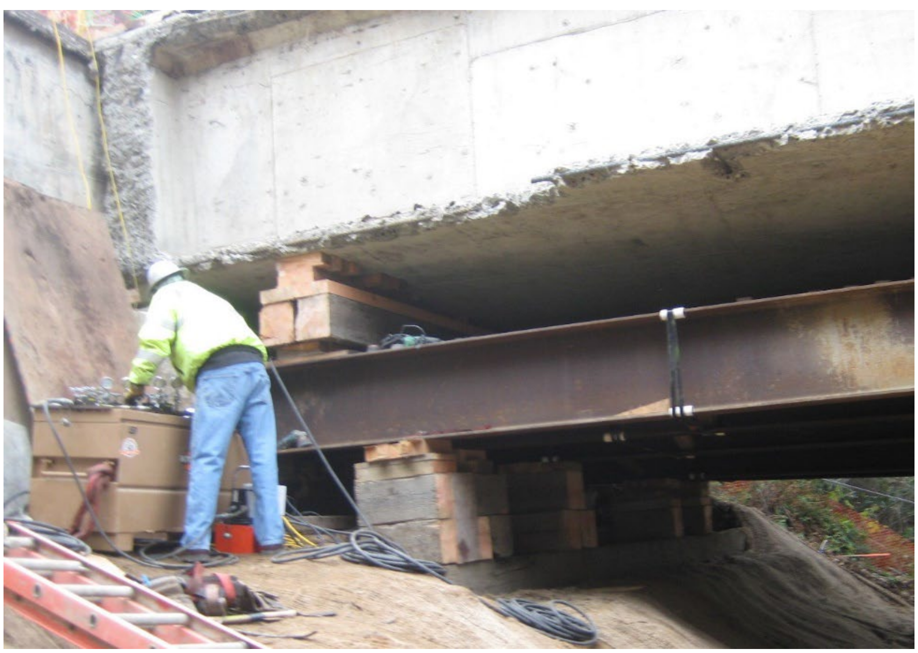

Figure 3-17. Combined Temporary Supports, Falsework, and Protective Cover, Elk

All these scenarios require close attention to detail by the Structure Representative since there may be many loading scenarios applied to the temporary supports at different stages of use. There may be additional loading applied to the temporary supports that was not anticipated in the contract plans, such as heavy equipment.

Hydraulic jacking systems are typically employed to transfer the vertical load to the temporary support, as illustrated in Figure 3-19. Careful monitoring of the bridge is required during jacking operations as required by the *Contract Specifications,* Section 48-5, *Temporary Structures – Jacking.*

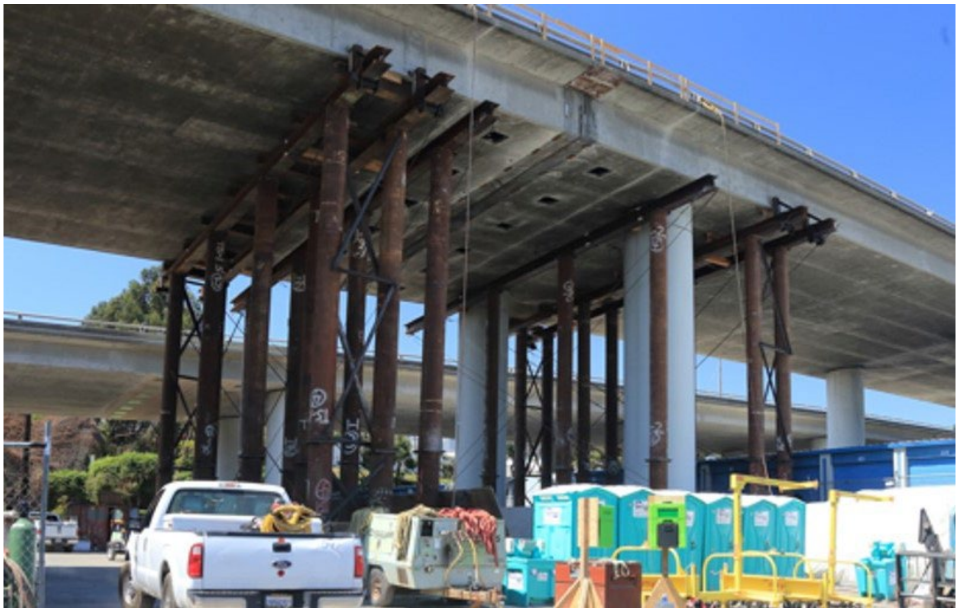

Figure 3-18. Hinge Temporary Supports, San Francisco

Figure 3-19. Jacking System Transferring Load to Temporary Support, San Francisco

3-7 Special Locations

3-7.01 Cantilever Steel Truss Bridges

Large cantilever steel truss bridges are complex structures with heavy and complex loads that require extensive planning and design to remove safely. These structures usually have many contract plan sheets dedicated to the removal sequence and loads. The Contractor usually has a detailed bridge removal work plan (or multiple plans) that is reviewed by both the Structure Representative and bridge design engineer and may involve other specialists to complete the review. These structures are sometimes retrofitted for various reasons and may have smaller scale, elemental bridge removal that still requires extensive review of the bridge removal work plan.

3-7.02 Suspension Bridges

Complete removal of suspension bridges is uncommon. However, like cantilever steel truss bridges, they are subject to various retrofits or rehabilitation which may involve partial or staged/sequenced bridge removal, as illustrated in Figure 3-20. Since suspension bridges are complex structures, a detailed analysis is required when removing and replacing structural elements.

Figure 3-20. San Francisco-Oakland Bay Bridge Retrofit Included Partial Bridge Removal on a Suspension Bridge