CHAPTER

12 Cofferdams and Seal Courses

12-1 General

A cofferdam is a retaining structure, usually temporary in nature, which is used to retain water and support the sides of excavations where water is present. These structures generally consist of: (1) vertical sheet piling, (2) a bracing system composed of wales, struts, or tiebacks, and (3) a bottom seal course to keep water from piping up into the excavation or to prevent heave in the soil. Cofferdams differ from braced excavations or shoring in that they are designed to control the intrusion of water from a waterway and/or the ground.

A seal course is a concrete slab poured under tremie to block the intrusion of water into the bottom of an excavation. The limits of the cofferdam are the limits of the seal course and the thickness is calculated to address engineering considerations such as pressures from differential hydrostatic head at the bottom of footing elevation.

12-2 Sheet Piles and Bracing

There are three basic materials used for the construction of sheet piles: wood, concrete, and steel. Wood sheet piling can consist of a single line of boards or “single-sheet piling” (Figure 12-1), but it is suitable for only comparatively small excavations where there is no serious ground water problem.

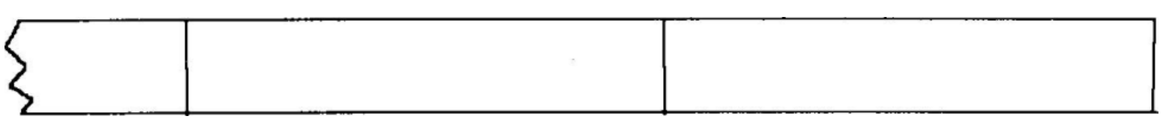

Figure 12-1. Single Sheet Piling.

In saturated soils, particularly in sands and gravels, it is necessary to use a more elaborate form of sheet piling which can be made reasonably watertight with overlapping boards spiked or bolted together, such as the “lapped-sheet piling” or “Wakefield” system (Figure 12-2).

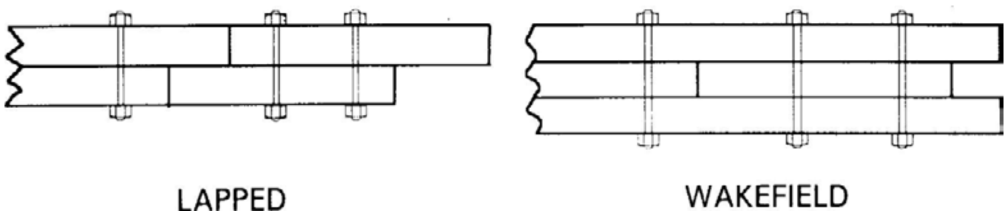

Figure 12-2. Lapped and Wakefield Sheet Piling.

"Tongue and groove" sheet piling (Figure 12-3) is also used. This is made from a single piece of timber that is cut at the mill with a tongue and groove shape.

Figure 12-3. Tongue and Groove Wood Sheet Piling.

Precast concrete sheet piles (Figure 12-4) are normally used in situations where these members are going to be incorporated into the final structure or are going to remain in place after they fulfill their purpose. Caltrans does not normally encounter precast concrete sheet piling in structure work. However, it is usually made in the form of a tongue and groove section. They vary in width from 18 to 24 inches and in thickness from 8 to 24 inches. They are reinforced with vertical reinforcing steel bars and hoops in much the same way that is done with precast concrete bearing piles. This type of sheeting is not perfectly watertight; however the spaces between the piles can be grouted to try to address this.

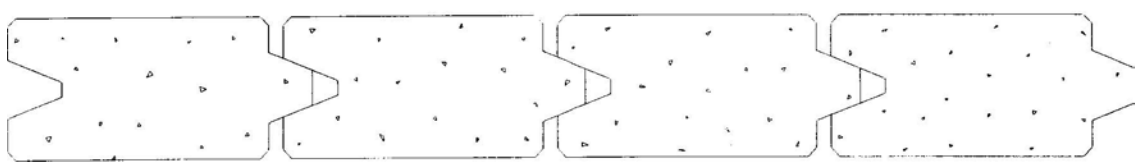

Figure 12-4. Concrete Sheet Piling.

In order to provide a more watertight precast concrete sheet pile, two halves of a straight steel web sheet pile, which has been split in half longitudinally, are cast into the concrete pile during fabrication (Figure 12-5).

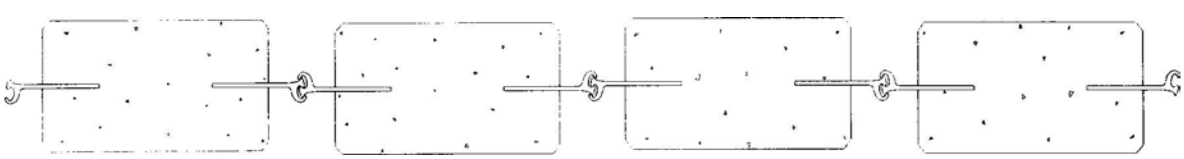

Figure 12-5. Concrete Sheet Piling with Steel Interlocks.

Steel sheet piling is most commonly used in the field. It is available in a number of different sizes and shapes. The shape provides bending strength and each end is fabricated with an interlock (connection between sheets) that provides alignment and interconnectivity between sheets. Each steel company that manufactures sheet piling has its own shape and form of interlock. The simplest shape is known as the "straight-web" (Figure 12-6). These are made in various widths ranging from about 15 to 20 inches. The web thickness varies from about 3/8 to 1/2 inch. The straight-web sheet piling is comparatively flexible and it requires a considerable amount of bracing in deeper excavations where lateral loads from waterways and soils are large.

Figure 12-6. Straight-Web Steel Sheet Piling.

In order to provide greater resistance to bending, the steel companies have developed sheet piles in a variety of shapes. One type is known as the "arch-web" section (Figure 12-7), where the center of the sheet is offset to provide a greater moment of inertia in the cross section. A "deep-arch" section (Figure 12-8) provides an even greater stiffness. It is similar to the "arch-web" except that the offset in the web is considerably larger. A third type, known as the "Z-Section" (Figure 12-9) has considerably greater stiffness than that of the "deep-arch" and is used in deeper excavations.

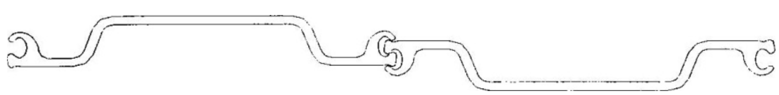

Figure 12-7. Arch-Web Steel Sheet Piling.

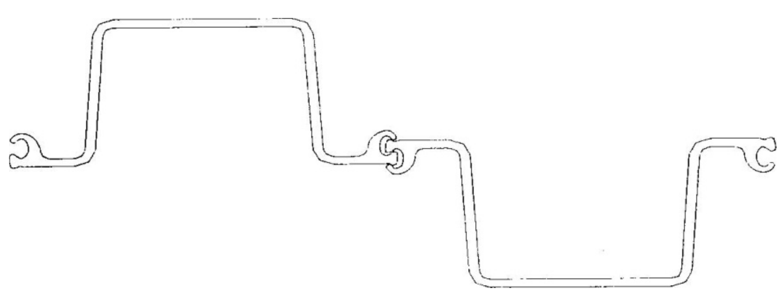

Figure 12-8. Deep-Arch Steel Sheet Piling.

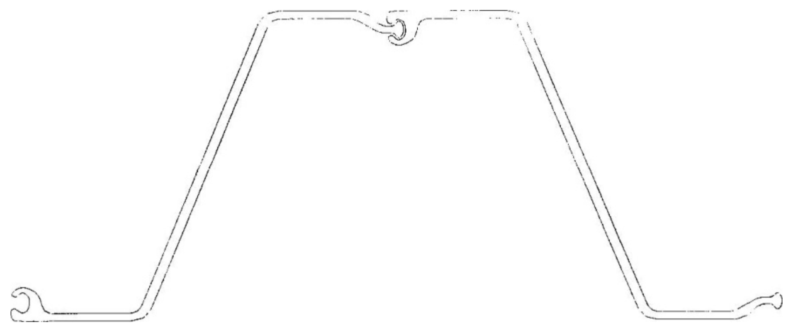

Figure 12-9. Z-Section Steel Sheet Piling.

The choice of the type of steel sheet pile to be used on a given project depends largely on the kind of service in which it will be used. The straight-web is comparatively flexible so it requires a considerable amount of bracing to resist large lateral loads in excavations. However, its cross section allows it to be used in locations where space is an issue and where a deep-arch or Z-Section will not fit in between the excavation limits and an obstruction or Right-of-Way line.

The composition of the bracing system inside the cofferdam will depend upon the forces that system must resist, the availability of materials, and the costs connected with the system. Ground anchors can be used in large land cofferdams where a system of cross bracing is impractical.

12-3 Excavation

Cofferdams in waterways are typically excavated with a submerged clamshell bucket, with the excavation elevations being checked by sounding. In the case of pile foundations, it is often advisable to over-excavate a predetermined amount to compensate for possible heave of the foundation material caused by driving piles; displacement piles in particular. This is done to eliminate the need for excavation after driving. If excavation is needed, care needs to be taken so as not to damage any of the driven piles.

To ensure the stability of the excavation, a seal course is used to control the influx of water into the excavation from the bottom due to hydrostatic head differentials. The contract plans show where seal courses are required. As in many other areas of our work, there are times when engineering judgment should be used to make decisions. Depending on the types of soils and the depth of the excavation in relation to that of the water table, the cofferdam may be dewatered without constructing a seal course while still allowing construction of the footing in the dry. The decision to use a seal course that is shown on the contract plans, or to revise its thickness, is the responsibility of the Engineer. Discussions about the need for a seal course or revisions to thickness need to take place early so that design considerations for the cofferdam can be addressed.

Seal courses for cofferdams might not be shown on the contract plans but may be needed to facilitate construction and provide a quality product. If a seal course is not shown on the contract plans and the Contractor elects to use one to control and remove water from the excavation, the work must be done in accordance with the provisions of the contract specifications[1].

12-4 Seal Course

The contract specifications[2] state that a seal course should be used when the Engineer determines it is impossible or inadvisable to dewater an excavation prior to pouring concrete. As the name implies, a seal course seals the entire bottom of a cofferdam and prevents subsurface water from entering the cofferdam. It also controls the expansion of soils that have a tendency to expand or heave. Sealing the bottom of the cofferdam allows cofferdams to be dewatered and permits the construction of footings, columns or other facilities in the dry. The seal course is a concrete slab placed underwater by the tremie placement method and is constructed thick enough so that its weight is sufficient to resist uplift from hydrostatic forces. The friction bond between the seal course concrete, the cofferdam, and piles if present, also helps resist uplift. A seal course is a construction tool and in terms of importance to the designed structure it has no structural significance.

Following the installation of the cofferdam and prior to dewatering, the soil is excavated to the elevation of the bottom of the seal course, and the piles are driven. The seal course is poured under tremie and allowed to cure. The cofferdam is dewatered after the seal course has cured. A small area of the seal course can be left low for the placement of a pump to remove water that seeps into the excavation prior to the placement of footing concrete.

Information about seal courses for a project can be found in the contract plans. Additional information may be found in the *Foundation Report* or RE Pending File. As previously discussed, when seal courses are shown on the contract plans, the decision about the need for the seal course and its thickness rests with the Engineer. This decision is based on conditions encountered on the jobsite. The contract specifications[3] also contain provisions for adjusting excavation item quantities if seal courses are adjusted or eliminated. Additional information about seal courses can be found in Bridge Construction Memo 130-22.0, *Seal Courses*. Bottom of footing elevations should not be revised as a result of eliminating or revising seal courses unless shown on the contract plans or addressed in the special provisions.

[1] 2010 SS, Section 19-3.03D, *Water Control and Foundation Treatment,* or 2006 SS, Section 19-3.04, *Water Control and Foundation Treatment*.
[2] 2010 SS, Section 51-1.03D(3), *Concrete Placed Under Water,* or 2006 SS, Section 51-1.10, *Concrete Deposited Under Water*.
[3] 2010 SS, Section 19-3.04, *Payment,* or 2006 SS, Section 19-3.07, *Measurement*.

12-4.1 Concrete Deposited Underwater (Tremie Placement Method)

The Tremie Placement Method is a name given to the method of placing concrete under water through a pipe or tube, known as a tremie, or with a concrete pump. The tremie can either be rigid or flexible. The purpose of the tremie is to enable continuous placement of concrete, monolithically, underwater without creating turbulence. Essentially the water is displaced by a slowly moving concrete mass.

To accomplish this, it is imperative that the discharge end of the tremie be kept embedded in the concrete. It is also imperative that the concrete have good flow characteristics. Concrete placement can be accomplished by either a tremie supported and maneuvered by a crane or the discharge end of a concrete pump. Frequently contractors will use multiple-tremie systems with each hopper supported by bracing or walkways in the cofferdam. In this case, tremie spacing is controlled by the flow characteristics of the concrete.

A typical tremie operation begins with the tremie pipe being lowered into position with a plug or other device fitted into the pipe as a physical barrier between the water and concrete. Concrete is charged into the pipe to a sufficient height to permit gravity flow. The flow itself is started by slightly lifting the pipe. Once started, the concrete flow must be continuously maintained through the pipe. The operation continues until completion. The tremie pipe remains immersed in concrete during placement. Some factors that ensure success for this operation are:

Table 12-1. Seal Course Tremie Concrete Placement.

FACTOR	DESCRIPTION
1	Tremie concrete must have a slump of between 6 and 8 inches, per the contract specifications[4].
2	Concrete must contain a minimum of 675 pounds of cementitious material per cubic yard, per the contract specifications[5].
3	Concrete placement and the maneuvering of the tremie pipe must be done smoothly and deliberately.
4	Concrete delivery must be adequate and timely.
5	The concrete mix design should be geared to good flow characteristics.

12-4.2 Seal Course Inspection

A *Cofferdam and Seal Course Construction Checklist* is presented in Appendix K-3 to assist field personnel in preparing documents and inspecting fieldwork to ensure compliance with contract requirements.

In addition to the usual concrete placement requirements, such as access and suitability or adequacy of equipment, sufficient soundings of the bottom of the excavation should be

[4] 2010 SS, Section 90-1.02G(6), *Quantity of Water and Penetration or Slump,* or 2006 SS, Section 90-6.06, *Amount of Water and Penetration.*
[5] 2010 SS, Section 51-1.02B, *Concrete,* or 2006 SS, Section 90-1.01, *Description*.

taken to verify as-built elevations so that deficiencies can be addressed. Particular care should be given to the perimeter of the cofferdam and the pile locations, as excavation is somewhat difficult in these areas. If not completely excavated, ground elevations in these areas will be higher than those in easier to reach areas, which will result in a thinner than anticipated seal course. Soundings can be accomplished using a flat plate of suitable size and weight on the end of a rod or rag tape.

Sounding devices can also be used to determine the nature of the material (soft or firm). During the pour, soundings are again used to verify the elevation of the top surface of concrete. Because of the type of operation, surface irregularities can be expected, particularly in pile footings. The important thing is to check for proper thicknesses throughout and to address any excessively low spots.

Of the various devices available to plug the end of the tremie, an inflated rubber ball is about the most practical. A tip plug can cause long tremie pipes to float and should be used with caution.

12-4.3 Thickness of Seal Course

A chart for determining the thickness of seal courses is included in Appendix I. Certain safeguards or safety factors are built into this chart. For example, seal courses in pile footings are constructed one foot thicker than required to allow for surface irregularities and the bond friction between sheet piling and concrete is disregarded. The bond friction between seal course concrete and foundation piles is limited to 10 pounds per square inch (PSI). Minimum thickness of seal course concrete is 2 feet. This subject is also covered in Bridge Construction Memo 130-22.0*, Seal Course* and Bridge Design Aids, *Seal Course* included in Appendix I, *Cofferdams and Seal Courses*.

12-5 Contractor's Responsibility

Cofferdams fall under the category of temporary features or measures necessary to construct the work. As such, the Contractor is responsible for the proper design, construction, maintenance, and removal of cofferdams. The Contractor is required to submit shop drawings and calculations to the Engineer for authorization in accordance with the contract specifications[6]. The Contractor is also required to comply with the applicable sections of the *Construction Safety Orders* (Sections 1539-1543) and the provisions of Section 6705 of the *California Labor Code*. Refer to the *Trenching and Shoring Manual* for additional information on braced or shored excavations.

The Contractor has the option of constructing a seal course to control water when one is not shown on the contract plans. In these situations the Contractor is responsible for determining the thickness and the performance of the seal course. The seal course

[6] 2010 SS, Section 5-1.23B(2), *Shop Drawings,* or 2006 SS, Section 5-1.02, *Plans and Working Drawings.*

thickness and curing requirements in the contract specifications[7] do not apply to optional contractor-designed seal courses. However, the successful performance of the seal course, if used, will be solely the responsibility of the Contractor.

12-6 Engineer's Responsibility

The Engineer is responsible for performing an independent analysis, or check, of the Contractor's cofferdam and for authorizing the shop drawings. In situations where a seal course is shown on the contract plans, the Engineer is responsible for making the decision as to whether or not a seal course is needed.

The Engineer should be familiar with the applicable information in the contract specifications[8] and Bridge Construction Memos 2-9.0*, Footing and Seal Course Revisions,* and 130-22.0*, Seal Courses*.

12-7 Dewatering

The contract specifications[9] require a minimum cure period of 5 days (at concrete temperatures of 45° F or more) before dewatering may begin. Dewatering can present some anxious moments since the cofferdam and the seal course will be put to the test.

Dewatering is sometimes conducted in stages, particularly for a deeper cofferdam. Intermediate bracing systems may need installed before proceeding deeper. Depending on the particular design, these internal braces maintain the stability of the system. Details of dewatering and internal bracing placement should be included in the cofferdam plans. A review of contract specifications[10] for water pollution control should be made before dewatering operations start.

Sheet pilings are not watertight and minor leaks can be expected as the cofferdam is dewatered. These leaks are ordinarily not a problem and occur along the joints between adjacent sheets. Sawdust, cement, or other material can be used to plug these types of leaks. Dropping the material into the water adjacent to the leaking sheets usually corrects

[7] 2010 SS, Section 19-3.03(D), *Water Control and Foundation Treatment,* or 2006 SS, Section 19-3.04, *Water Control and Foundation Treatment.*
[8] 2010 SS, Sections 5-1.23B(2), *Shop Drawings*, 19-3.03C, *Cofferdams*, 19-3.03D, *Water Control and Foundation Treatment,* 19-3.04, *Payment*, 51-1.03D(3), *Concrete Placed Under Water*, & 51-1.04, *Payment*; or 2006 SS, Sections 5-1.02, *Plans and Working Drawings*, 19-3.03, *Cofferdams*, 19-3.04, *Water Control and Foundation Treatment*, 19-3.07, *Measurement*, 19-3.08, *Payment*, 51-1.10, *Concrete Deposited Under Water,* & 51-1.22, *Measurement.*
[9] 2010 SS, Section 51-1.03D(3), *Concrete Placed Under Water,* or 2006 SS, Section 51-1.10, *Concrete Deposited Under Water.*
[10] 2010 SS, Section 13-4.03G, *Dewatering,* or Special Provisions for contracts using 2006 SS.

this as the flow through the leak carries the fine material to the problem area and seals the crack or opening. A sump built into the surface of the seal outside of the footing limits is also helpful in keeping the work area reasonably dry.

Prior to proceeding with footing work, all high spots in the seal course have to be removed. All scum, laitance, and sediment must also be removed from the top of the seal. This work can be very time consuming and expensive. It can be reduced significantly if care is taken during the placement of the seal course.

12-8 Safety

Cofferdam work presents safety problems similar to braced excavations. Among them are limited access, limited work areas, damp or wet footing, and deep excavations. Provisions must be made for safe access and egress in terms of adequate walkways, rails, ladders, or stairs into and out of the lower levels. The *Trenching and Shoring Manual* goes into those issues in depth and should be consulted prior to working around cofferdams.

Additional considerations apply to cofferdams, as they tend to occur within a waterway, in which case additional safety regulations may apply. These include provisions for flotation devices, boats, warning signals, and suitable means for a rapid exit. The *Construction Safety Orders* and project-specific *Code of Safe Practices* should be consulted for specific requirements.