Oregon Department of Transportation

SECTION 1.16
Construction

Revisions for the current edition are highlighted yellow. Deleted text is not marked.

Past editions of the Bridge Design Manual are available through our website.

1.16.1 Bridge Raising

1.16.2 Accelerated Bridge Construction (ABC) Guidelines

1.16.3 Bridge Temporary Works

1.16 Construction

1.16.1 Bridge Raising

Provide enough information in the contract document to enable the construction contractor's engineer to design supporting elements for a bridge raising and stability of the structure during this operation.

See *BDM 1.3.4.2* for loading criteria related to bridge raising.

Temporarily pin concrete barriers that protect the bridge from damage from adjacent traffic. Provide at least 1 foot clearance between the barrier and the bridge or falsework elements. Do not allow traffic in the lane adjacent to the columns that **chip-in** is in progress.

When using the chip-in method take a concrete sample of each column to verify the column's concrete strength.

C1.16.1

There are two common construction procedures employed in raising a bridge: falsework or **chip-in** construction. The **chip-in** method of bridge raising removes concrete at the mid-point of each column to provide enough room to place a jack and shims. The remaining concrete is removed and the reinforcing steel severed. After the bridge deck is brought to the desired elevation, the severed reinforcing steel is spliced and the void between the two portions of the column is filled with non-shrink concrete.

1.16.2 Accelerated Bridge Construction (ABC) Guidelines

Oregon has a long history of employing ABC methods to quickly deliver bridge projects using a variety of techniques. Some were assembled or erected on temporary falsework located adjacent to an existing structure and skidded into place. This method allowed contractors to close the facilities to vehicular traffic for a relatively short time (a few days or weekend) and skid the bridge over after quickly demolishing the existing bridge at night and working through weekends. Other bridges over navigable waterways were replaced using barges to float new and whole superstructures into place (also known as switch out when an existing structure is replaced). For wider structures that can accommodate staged construction, precast concrete or concrete filled steel grid deck panels were installed using a partial closure of the roadway during off peak travel times.

A few Oregon ABC projects were designed with rapid construction in mind to limit traffic interruptions, but most were selected either based on VE proposals by contractors, incentive/disincentive provisions, or design-build contracts. Generally, the project schedules specified a relatively short window for closing or disrupting traffic operations on the facilities. The incentive/disincentive provision for each project was normally based on user delay costs as a function of AADT, detour length and other variables. Those projects have demonstrated ABC as an effective and efficient solution to alleviate congestion and long detours where conventional methods such as off-site detour, on-site detour, stage construction or slight realignment of the roadway were difficult or not feasible. They also resulted in improved public safety through a shortened work zone exposure.

1.16.2.1 ODOT encourages and supports ABC Projects

ABC methods can be defined as using prefabricated bridge elements, combining elements into systems, or moving a complete bridge span to quickly deliver a project and re-open a highway to traffic. Use of any of these methods are encouraged and supported by ODOT. A compiled list of past Oregon projects that described the ABC featured elements is provided here at the end of the section for reference.

Construction activity results in delays to the public and incurs additional financial burdens on the people who must contend with the effects. This essentially results in a temporary tax on the affected neighborhood. Because of this, consider ABC methods even when it does not result in the lowest overall construction cost. Designers are encouraged to consider traffic delay costs and other user costs associated with a project to support stronger consideration of ABC methods. The ABC AHP Decision Making Program presented in *BDM 1.16.2.3* is available to assist in developing support for ABC.

Prefabricated elements consisting of deck panels, beams or girders, bent caps, pier columns and segments have been demonstrated successfully. Systems may consist of bridge components assembled and connected together to form a major portion or complete bridge span. Bridge

movements such as incremental launching, skidding, and transport by self-propelled modular transporters (SPMT) of a partial/complete superstructure span are also found to be acceptable methods of construction. The guidance provided here will help designers and owners decide when and where ABC is appropriate as a method of project delivery. Although the Engineer of Record is responsible for the design as well as for developing a unique method of construction/movement to fulfill ABC requirements, the owner needs to be assured that quality and durability is not being compromised by the specific rapid construction technique being considered.

1.16.2.2 Contracting Methods Allowed

A contract for specifying ABC method of delivery is allowed and will continue to be allowed under the current design-bid-build specifications. A contractor may propose an alternate method of construction for approval by the EOR/owner as part of the Cost Reduction Proposal provisions in *SP 00140.70* of the Oregon Standard Specifications for Construction. The third option allowing ABC is provided under the design-build contract provisions. More discussions and guidance are provided elsewhere and will not be elaborated here.

1.16.2.3 Decision Making Framework

A successful ABC project is dependent on deciding correctly at the beginning of a project planning to assess when and where ABC would be most efficient and effective. The criteria in the flowchart, *Figure 1.16.2.3-1*, for specifying a short window of closure may make ABC delivery the method of choice.

Figure 1.16.2.3-1 Flowchart for Determining the Applicability of ABC

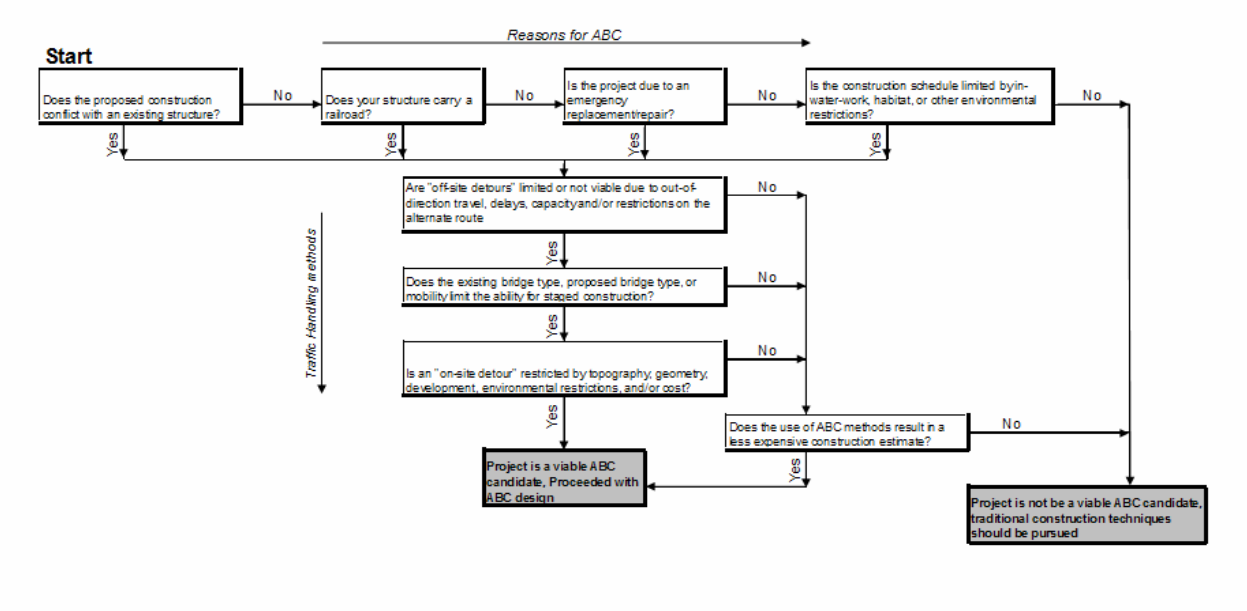


Table 1.16.2.3-1 is intended to help guide discussions when comparing ABC with conventional construction.

Table 1.16.2.3-1 Comparison of ABC with Conventional Construction Methods

ATTRIBUTES	**Accelerated BC (ABC)**	**Conventional BC (CBC)**
1. Complexity	-Engineer less familiar with design required for accelerated bridge construction techniques -May require more surveys to establish control points -May require pick points for prefabricated bridges -May require more complex construction techniques -May need new specs -May add risk to contractor -May require special equipment -Good with D/B and A+B with incentive/disincentive	-Engineer more familiar with design required for conventional construction techniques; therefore, considered less complex. - Contractors more familiar with methods used in conventional construction, therefore considered less complex -Standard specs exists
ATTRIBUTES cont.	**Accelerated BC (ABC) cont.**	**Conventional BC (CBC) cont.**
2. Schedule	-Facility to reopen for traffic in hours or over weekends -Slightly longer design schedule due to complexity (see above) -Need more overall planning and coordination -Parallel construction off CPM -Typically can be done off-line and shorter field erection season, pending ABC method chosen. -Approach or utility work may control schedule if not outside CPM -Good with incentive/disincentive -Constructible connection details for precast elements such as bent caps, footings & pile heads require flexibility for field closure pours. -May require coordinated demolition plan for change-over structures	- Typical field construction season in months or years -Typical design schedule -Often bridge work is controlling in CPM -Sequential activities typical and limitations may exist -Public delay cost may be high

	-May require tight control of scheduling on critical items -The contract plan or designed details should be simple or the precast element detail may not fit. -May require industry participation in PBES/ABC to ensure successful transition to field application. -Include contractor on design or constructability review team.	
3. Budget	-May be more expensive in construction cost due to non-typical construction methods -May increase design cost -Limited historical bid item data -ABC can significantly reduce the costs to highway users associated with traffic queues and detours during the bridge installation. -The contract bid cost for an ABC project may be more than a conventional bridge project but overall may be much less when the savings due to reduced traffic impacts and delays are factored in.	-Typical estimate given condition and conventional required structure type. -Typical standard project costs. -Incentives and disincentives may be included to accelerate construction and reduce traffic impacts but they may not be effective and could adversely impact project costs. -Careful analysis is needed to effectively apply incentive/disincentive methods to accelerate bridge projects.
4. Design Quality	-Design quality could be just as good as that of conventional -Limited design criteria for some elements -Construction loads may control design and need check -Require to show full connection details	-Design quality is expected to be good from standard and best practice.
ATTRIBUTES cont.	**Accelerated BC (ABC) cont.**	**Conventional BC (CBC) cont.**
5. Construction Quality	-Individual prefabricated elements are of higher quality under shop-controlled environment. -Construction quality could suffer in the field assembly due to time pressure.	-Construction quality depends on the contractor and inspection staff.
6. Disciplines required	-May require more upfront coordination between technical and non-technical disciplines and public relations.	-Standard project design and construction teams

7. Experience needed	-ABC experience is desirable especially regarding knowledge of ABC construction methods, new technologies and implementation of new design and details. -Additional research effort and resources may be required. -May require specialty construction experience.	-Standard project design experience. - Standard bridge construction experience.
8.Public Communications	-May require more early and upfront communication with the public for temp/short road closures -May need to develop a communication plan with stakeholders	- Typical
9. Demolition of existing structure	-Require full demolition plan -May need to provide staging place near site for off-line demolition -Coordination for change-over structures -May not require temporary structure to be in place for long duration	-Typical construction with either road closure or requires staging -Require full design of temporary structures for longer duration in place
10. Quality Control	-ABC elements should be verifiable during construction -May require constructability review	-Typical
11. Owner Staff	-Some additional effort may be expected of the owner staff in design or review of non-conventional details/procedures. Also may require more staff in a much more condensed timeframe.	-Standard

1.16.2.4 Analytic Hierarchy Process (AHP) Tool

ODOT has a tool for assisting project decision makers named *ABC AHP Decision Making Program*. This program allows the project team to analyze various applicable and weighted criteria in a paired-wise comparison. With input provided either by the designer or the project team, it captures the decision based on the controlling criteria and computed utility value for each criteria.

We encourage all project designers and leaders to take advantage of this useful tool as part of their decision making process to determine whether ABC is preferred over conventional construction. This program may be used with input provided by the bridge engineer alone if they have all the available information and feels comfortable to determine the relative importance between any two given criteria. When a project is complex and involves issues or concerns by other disciplines, it would be appropriate for the project team to provide input and

thus build consensus in their decision making process. Input can be collected with a survey form or entered directly into the program data fields either during or after the project kick-off meeting or when more information become available for them to better gauge the relative importance between any given paired criteria or sub-criteria.

1.16.2.4.1 Instructions for using the "ABC AHP Decision Making Program"

The AHP Program (in short) must be first loaded onto a personal desktop or laptop computer and must include the **dotNetFx40_Full_x86_x64.exe**. It is recommended the AHP Program be copied into a separate folder. It is assumed one is familiar through reading the manual (included in the CD folder) or attended the training. In summary, here are the logical steps to get started in running the program:

- Individual or team to establish the applicable criteria and sub-criteria for ABC decision. Refer to *Figure 1.16.2.4.1-1* and mark the ones that apply to the specific project in question. Reminder: Always save your work.
- Optional step: Use the survey form to assign the relative value for each paired-wise criteria comparison OR skip to next step.
- Run the Program by clicking on **AHPTool.exe** file. This will open the program under Tab 1 (Decision Hierarchy) and de-select the non-applicable criteria and sub-criteria determined in Step 1. User can add a new criterion or remove one from the default by using the **add child** or **remove** button on the right.
- Then click on Tab 2 (Pairwise Comparison) and enter the relative values from Step 2. Reminder: Always save your entries.
- Click on Tab 3 (Results)
- To use Tab 4, please read and follow instructions in the Manual.

1.16.2.4.2 Established Criteria and Sub-criteria for ABC decision

See *Figure 1.16.2.4.2-1*. Most transportation project decision making require some criteria that are important and specific to each site. Five main level criteria have been established and they seem to be the standard criteria used by several states for decision with ABC projects. Within each main level criterion is further defined by a sub-criterion that further expands to differentiate its elements. The definitions for each criterion are provided in *Table 1.16.2.4.2-1*.

Figure 1.16.2.4.2-1 Criteria for ABC Decisions

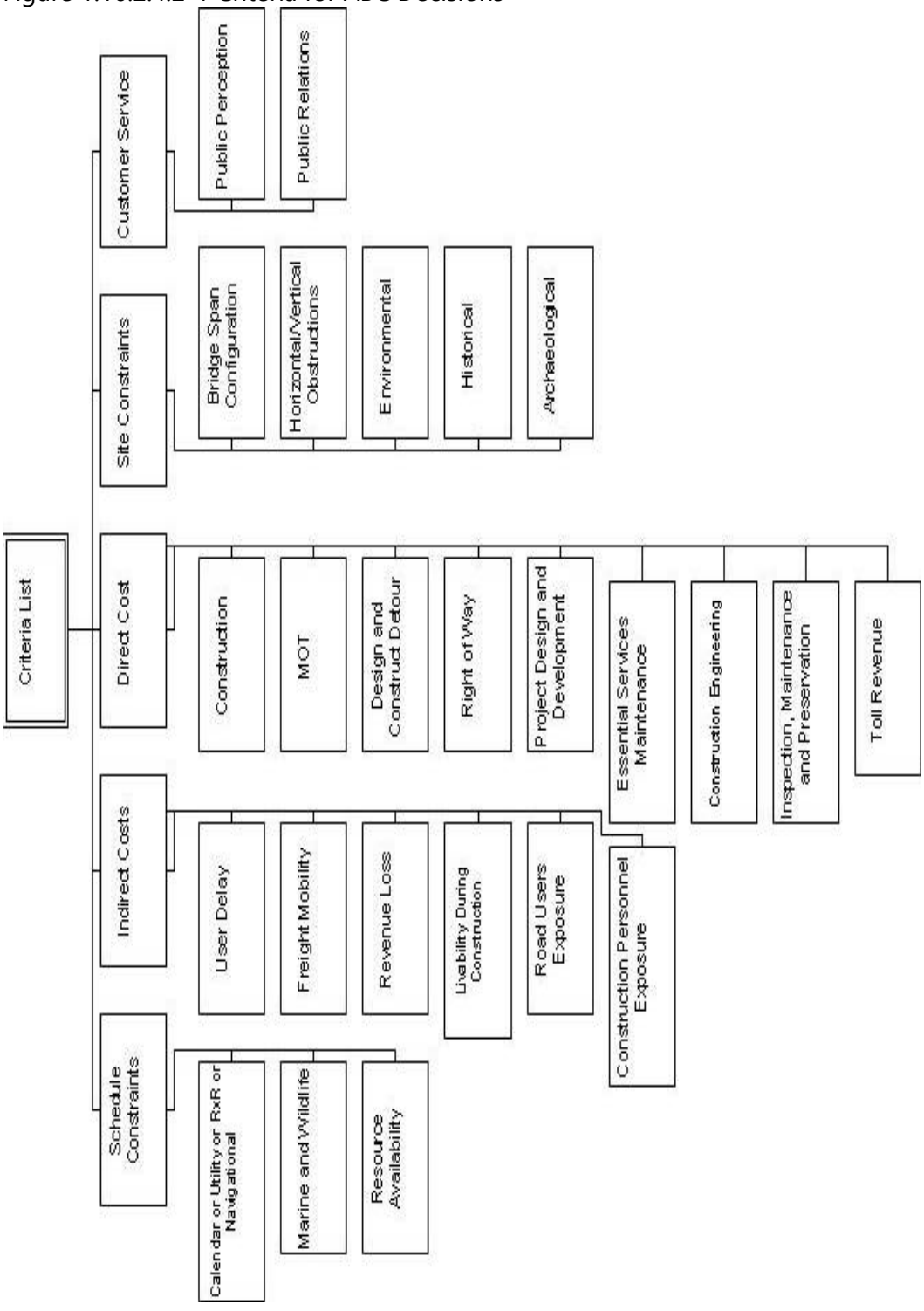


Table 1.16.2.4.2-1 Definition List of ABC Criteria

Main criteria	Sub-criteria	Definition
Direct Costs	Construction	This factor captures the estimated costs associated with the construction of the permanent structure(s) and roadway. This factor includes premiums associated with new technologies or innovative construction methods. Premiums might result from factors such as contractor availability, materials availability, and contractor risk. It may include incentive/bonus payments for early completion and other innovative contracting methods.
	Maintenance of Traffic (MOT)	This factor captures the maintenance of traffic costs at the project site. MOT costs may impact preference due to its impact on total costs. This factor includes all costs associated with the maintenance of detours before, during, and after construction. Examples of this factor include; Installation of traffic control devices, maintenance of detour during construction including flagging, shifting of traffic control devices during staged construction, restoration associated with the temporary detours upon completion of construction.
	Design and Construct Detours	This factor captures the costs to design and construct temporary structures and roadways to accommodate traffic through the project site.
	Right of Way (ROW)	This factor captures the cost to procure ROW. This factor includes either permanent or temporary procurements/easements.
	Project Design and Development	This factor captures the costs associated with the design of permanent bridge(s) and costs related to project development based on the construction method.
	Maintenance of Essential Services	This factor captures the costs associated with the need to provide essential services that may be impacted by the construction selected. Examples of this factor include alternate routes or modes of transportation to provide defense, evacuation, emergency access to hospitals, schools, fire station, and law enforcement, etc. This criterion is for situations where measures needed to be implemented beyond those already considered in the MOT and Design and Construct Detours criteria.
	Construction Engineering	This factor captures the costs associated with the owner's contract administration of the project.
	Inspection, Maintenance and Preservation	This factor captures the life cycle costs associated with the inspection, maintenance and preservation of individual bridge elements.
	Toll Revenue	This factor captures the loss of revenue due to the closure of a toll facility.

Main criteria cont.	Sub-criteria cont.	Definition cont.
Indirect Costs	User Delay	This factor captures costs of user delay at a project site due to reduced speeds and off-site detour routes.
	Freight Mobility	This factor captures costs of freight delay at a project site due to reduced speeds and off-site detour routes.
	Revenue Loss	This factor captures lost revenues due to limited access to local business resulting from limited or more difficult access stemming from the construction activity.
	Livability During Construction	This factor captures the impact to the communities resulting from construction activities. Examples include noise, air quality, and limited access.
	Road Users Exposure	This factor captures the safety risks associated with user exposure to the construction zone.
	Construction Personnel Exposure	This factor captures the safety risks associated with worker exposure to construction zone.
Schedule Constraints	Calendar or Utility or RxR or Navigational	This factor captures the constraints placed on the project that might affect the timing of construction as a result of weather windows, significant or special events, railroad, or navigational channels.
	Marine and Wildlife	This factor captures the constraints placed on the project by resource agencies to comply with marine or wildlife regulations. Examples include in-water work windows, migratory windows, and nesting requirements.
	Resource Availability	This factor captures resource constraints associated with the availability of staff to design and oversee construction. For example, a state may be required to outsource a project, which may result in additional time requirements.
Site Constraints	Bridge Span Configurations	This factor captures constraints related to bridge span configurations. This element may impact owner preference regarding bridge layout, structure type, or aesthetics.
	Horizontal/Vertical Obstructions	This factor captures physical constraints that may impact construction alternatives. Examples include bridges next to fixed objects such as tunnels, ROW limitations, sharp curves or steep grades, or other urban area structures that constrain methods or bridge locations.
	Environmental	This factor captures the constraints placed on the project by resource agencies to minimize construction impacts on natural resources including marine, wildlife, and flora.

	Historical	This factor captures historical constraints existing on a project site.
	Archaeological Constraints	This factor captures archaeological constraints existing on a project site.
Main criteria cont.	**Sub-criteria cont.**	**Definition cont.**
Customer Service	Public Perception	This factor captures both the public's opinion regarding the construction progress and their overall level of satisfaction.
	Public Relations (PR)	This factor captures the costs associated with the communication and management of PR before and during construction.

1.16.2.5 Steel Structures

Steel structures are excellent examples of prefabricated bridge elements and systems. They are proven to be cost effective for ABC applications. Steel girders are prefabricated and prime-coated as needed in the shop and shipped to the job site. A short closure of the affected highway facility may be required to erect them. Complete arches and trusses have been erected successfully on barges and floated into place.

Bridges built with plate girders (straight or curved) can accommodate precast concrete panels or steel grid deck systems for rapid construction. Sample connection details can be found at www.fhwa.dot.gov/bridge/prefab/

1.16.2.6 Concrete Structures

1.16.2.6.1 Prestressed and Precast Concrete (PPC) vs Cast-In-Place

PPC bridge elements are typically mass produced in a PCI-certified plant under factory-controlled conditions. This results in a high quality product. PCC products can be transported to the jobsite for just in time delivery, thus avoiding re-handling or the need for storage space that might be difficult to provide in urban areas. Traffic impact at the project site can be minimized and erection can normally be done during off peak hours.

In Oregon, construction cost for PPC girders is lower than CIP girders. Unless there is a compelling reason like curvature, aesthetics, and longer span requirements, PPC girders are preferred. There is economy of scale for larger projects requiring repetition of similar spans. For elements other than girders, there is opportunity to develop effective standard elements for connecting them into bridge systems. In the erection of PPC elements, proven connection details are critical for long term performance. The FHWA has developed a manual on proven connection details found here: www.fhwa.dot.gov/bridge/prefab/

1.16.2.7 Full Depth Deck Panels, Approach Slabs or Approaches and

Wingwalls

Full depth deck panels are used by many states. Connection details for both steel and concrete girders exist. A survey of details used by various states was published in 2006 as NCHRP 12-65. ODOT has constructed multiple projects using full-depth precast concrete deck panels, but has not yet settled on a standard detail. ODOT does not allow partial-depth precast deck panels. ODOT has existing standards for approach slabs/approaches and wingwalls that can be readily converted into ABC.

1.16.2.7.1 PRECAST APPROACH SLABS

- Consider issues regarding subgrade compaction and the contractors' ability to construct the surface of the subgrade to a smooth level condition prior to placement.
- Consider the ability of precast slabs to accommodate differential settlement (especially if subgrade is not level).
- Consider the design of the connection detail to pile cap/abutment wall and any joint construction.

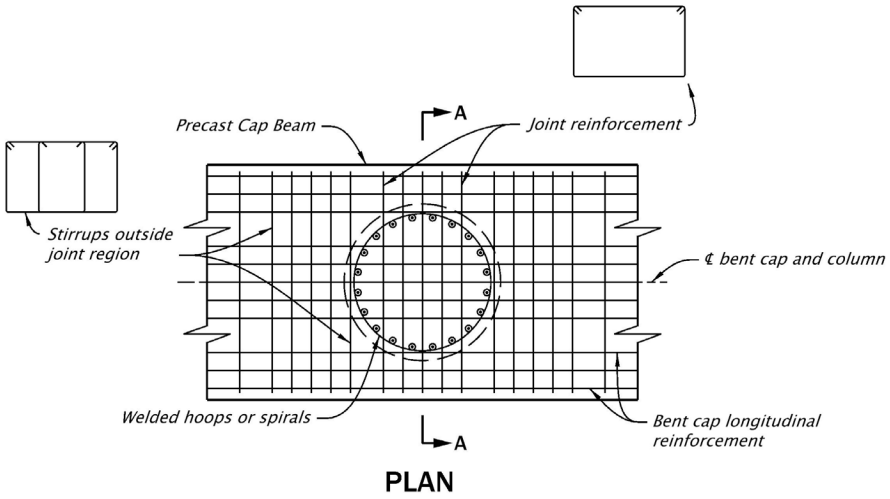
1.16.2.8 Precast Connections in Seismic Regions

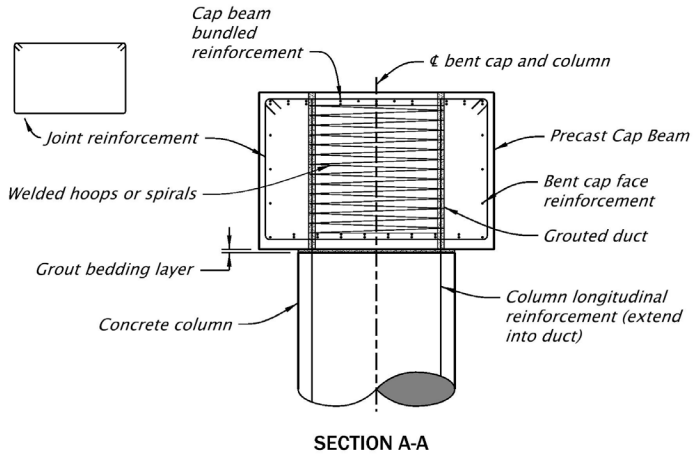
When assembling prefabricated bridge elements on site, a detailed assembly plan may be needed. For single span bridges assembly is typically not complicated. For multi-span bridges, designing and detailing of connections has to be treated with the same importance as designing the rest of the structure.

Submit new connection proposals for approval to Bridge Design Manual Standards Engineer. This requirement is intended to ensure information about good connection details are subsequently distributed to other design groups. Research into new connection details has been ongoing with special concern for finding details that perform well under seismic loading. The *NCHRP 12-74* research project *Development of Precast Bent Cap Systems for Seismic Regions* identified a number of bent cap-to-column details that hold promise for seismic applications. Their conclusions were released in 2011 as *NCHRP Report 681*. ODOT is willing to implement a few of these details only for bridges in low-to-moderate seismic regions (Seismic Zones 1, 2 or 3):

- Grouted Duct – Grouted duct connections consist of bent caps which have corrugated ducts to accept reinforcement extending from supporting substructure elements.

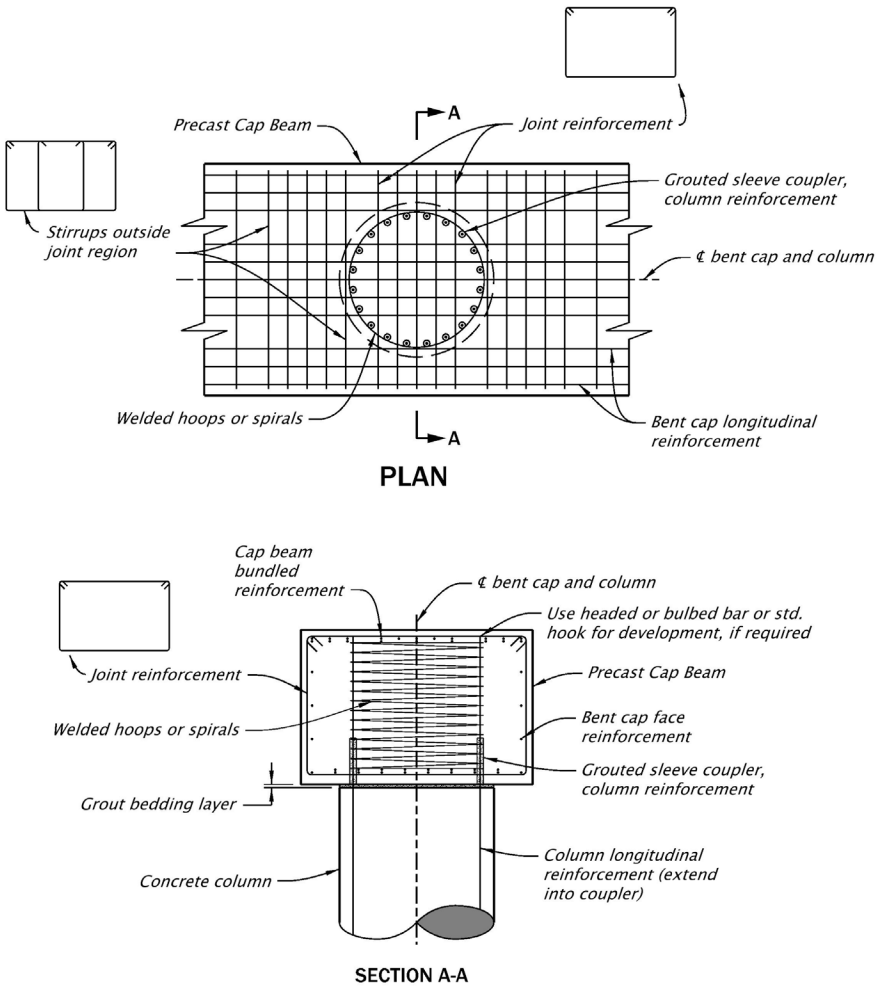
Figure 1.16.2.8-1 Grouted Duct Connection to Achieve Full Ductility.





- Grouted Sleeve Coupler (Coupler in Cap) – Proprietary grouted sleeve couplers are used to connect reinforcing bars in precast concrete components. These couplers are placed in the bottom-half of the precast bent cap and are designed to withstand forces at overstrength as is often required in plastic regions.

Figure 1.16.2.8-2 Grouted Sleeve Coupler Connection to Achieve Full Ductility



1.16.2.9 Use of Self-Propelled Modular Transporters (SPMT)

SPMTs can support and move heavy loads using a flat-bed mounted on multi-axle, independent suspension and steering wheel lines. They have the ability to maneuver in difficult and uneven terrain with unmatched precision and distortion control of the payload.

SPMTs can move complete superstructure spans from a staging area (e.g. gore area or off the shoulders) to the final bridge location. A bridge move can be performed on weekends or at

night using the SPMTs to erect a structure into final position within a matter of hours. FHWA has a user guide manual as a resource for anyone contemplating an ABC project using SPMTs. The guide is available free of charge at http://www.fhwa.dot.gov/bridge/pubs/07022/.

1.16.2.10 Geotechnical Considerations

Geotechnical designers need to consult closely with the bridge designer and the project team regarding the use of ABC methods at a particular bridge site. Continue to coordinate these efforts as necessary during the bridge design process.

Driven piling is normally the most rapidly constructed foundation type. However, piles are not suitable at every location. The most suitable foundation type for a bridge replacement or widening project depends on several factors including the subsurface materials and conditions, construction or environmental constraints and cost. Refer to the *ODOT GDM; Chapter 8* for additional guidance regarding the selection of foundation types. Once the most suitable foundation type is selected for a site, thought should be given to how the foundation construction can be expedited. This should include how to minimize traffic impacts due to foundation construction. At some locations the foundations (and substructure elements) may be constructed under, or away from, the existing bridge thereby avoiding, or minimizing, any traffic impacts. If this scenario is possible, the time required for foundation construction may be less significant because it does not directly affect traffic. At sites where foundation construction will directly impact traffic and multiple foundation types are possible, consideration should be given to the foundation system that can be constructed in the least amount of time and with the least impact to traffic. Some general guidance regarding the use of various foundation systems in ABC applications are described below.

1.16.2.10.1 Spread Footings

CONVENTIONAL SPREAD FOOTINGS

- Requires excavation to suitable foundation materials which may result in the need for large excavation areas or temporary shoring and possibly dewatering.
- Requires setting rebar, a concrete pour and curing time (and form work, if needed).

PRECAST REINFORCED CONCRETE SPREAD FOOTINGS

This type of ABC foundation system is currently under development. Design and construction standards and specifications do not currently exist. This type of foundation may be considered at sites where conventional spread footings would be appropriate. Precast spread footings (PSF) are currently recommended only for shorter, single span bridges at this time. Issues to consider in the application of precast spread footings would include:

- Need for construction of a concrete footing leveling slab beneath the precast footing (excavation/shoring, sloping bearing strata, presence of groundwater, etc.).

- Design of the connection between PSF and leveling slab.
- Design of the connection between the PSF and columns or abutment walls.
- Constructability issues when placing PSF directly on compacted soils.
- *LRFD* resistance factors for bearing and sliding resistance based on construction method, and settlement analysis.

1.16.2.10.2 Driven Piles

Often the quickest foundation construction method and can generally have the least impact and disruption to traffic.

- Consider using fewer, higher capacity, piles per bent to expedite construction, however:
    - Using higher capacity piles may result in significantly higher foundation costs due to the need for larger pile driving hammers, leads and cranes and possible effects on the cost of work bridges due to these higher loads.
    - Using less than five piles per bent may result in a reduced *LRFD* resistance factor due to less redundancy.
    - May be most appropriate for sites with relatively short end bearing piles.
- Requires assessment of pile top alignment tolerances for precast pile cap connection:
    - Standard specifications (*SP 00520.41(f)*) allow for a horizontal alignment tolerance of 6 inches from the plan location. If a smaller tolerance is required this reduced tolerance must be specified in the special provisions. Consult with the project geotechnical engineer regarding allowable horizontal tolerances for driven piles.
    - Should piles be installed in prebored holes to meet the specified tolerances? Keep in mind the final pile alignment is only as good as the prebore hole alignment. In soils where large cobbles or boulders are present, or where preboring will encounter a bedrock unit with a sloping surface, prebored holes should not be augered but instead excavated using core drilling equipment. Augers tend to wander uncontrollably in these materials and borehole alignment is very difficult to maintain.
    - Consider the time and cost of preboring.
    - Consider the risk of not preboring (possibly include preboring as an anticipated item).
- Minimize the potential for in-lead splices, particularly on pile with a wall thickness of greater than ½ inches such that extensive welding and welding QA/QC is not required.
- Increasing estimated lengths in variable subsurface conditions will help reduce the likelihood of an in-lead splice for pile shorter than 60 feet. For longer pile consider specifying that the pile be fabricated (spliced) on site prior to putting in the leads, taking into account the cost of using larger size leads and cranes and other concerns similar to those discussed above when using fewer high capacity pile.

- Piles can be installed in existing travel lanes, in stages under traffic control, and covered over with temporary steel cover plates to keep travel lanes open to traffic until the time for substructure construction.
- At water crossings consider a trestle pile design which eliminates the need for a cofferdam (if an above ground pile cap is permissible). Potential for drift buildup should be assessed relative to the use of a trestle pile system. A web wall may be required if drift potential is significant.

1.16.2.10.3 Drilled Shafts

- Usually takes the most time to construct. Drilled shafts are often the best method for rapid in-water foundation construction, since they may omit the need for a cofferdam (unless required for environmental considerations).
- Consider fewer, higher capacity, shafts per bent, (note that appropriate modifications to *LRFD* resistance factors are required for bents with less than two shafts).
- Higher potential for increased risk of time delays due to problems with shaft construction or negative NDT results.

1.16.2.10.4 Micropiles

- Usually more expensive than other foundation types.
- Suitable for certain ground conditions, particularly manmade unconsolidated rock fragment fills and low overhead clearance areas.
- May be installed to tight tolerances and drilled through pavement sections.
- Consider environmental concerns relative to spoils recovery since water is typically used to flush out cuttings.

1.16.2.11 Accelerated Embankment Construction

The time required for embankment construction, (either an all new roadway embankment or a widening section) depends primarily on the volume of material required, the type of embankment materials used, the level of contractor effort and the subsurface conditions at the site. Other factors such as access, retaining wall construction and weather can also play a role and affect the speed at which an embankment can be constructed. Embankment construction may be accelerated in a number of ways. In areas where very soft ground conditions exist there is potential for significant settlement and stability issues. Consideration should be given to extending the bridge structure over these areas. This may result in a better overall design with less environmental impacts and a shorter construction period.

For ABC projects, the geotechnical engineer is responsible for evaluating the site conditions and project requirements to determine the most effective way of expediting embankment construction with the least impact to traffic flow and mobility. Refer to *ODOT GDM; Chapter 9* for more design guidance on the analysis and design of embankments. ABC projects often replace bridges in the same location (same horizontal alignment) as the existing bridge with the

new bridge being wider. Therefore approach embankments also need to be widened. The grade may also be raised resulting in a further increase in embankment widening. Depending on the site constraints (available access/ROW, adjacent structures, wetlands, etc) this widening can often be accomplished with minimal traffic impacts. The geotechnical engineer plays a key role in the design of these widened sections to help determine the best approach for expediting construction while taking all appropriate geotechnical design requirements into account.

The need for retaining walls on a project should be carefully reviewed. Typically an embankment can be constructed quicker than a retaining wall. Retaining wall needs are typically driven by roadway **typical section** needs that may not have been optimized to reduce the need for retaining walls. For example, the slope immediately behind a guardrail could be steepened from the typical 1V:3H or 1V:4H to steeper slopes if longer (8 foot) guardrail posts are used rather than the typical 6 foot post lengths. Often typical fill slope rates of 1V:2H are considered in typical sections. Steeper slopes, when permitted, may omit or reduce the need for a wall. Use of stone embankment material may allow fill slopes to be constructed as steep as 1V:1.5H. If so, 8 foot metal guardrail posts may be needed to assist in penetrating the stone embankment material.

Retaining walls may be proposed in some areas to avoid, or minimize, environmental impacts. The need for walls in these areas should be closely evaluated, in consultation with the appropriate environmental specialists, to determine the underlying reasons for requiring a wall and whether or not it is the best solution for the specific location.

Some suggested considerations for embankment construction on ABC projects are summarized below:

- Use **All-Weather Materials** (stone embankment) instead of common **borrow** materials where available and appropriate. This allows construction to rapidly proceed regardless of wet weather conditions and can greatly reduce the total embankment construction time.
- Soft Ground Conditions (settlement and stability issues)
    - Lightweight fill material such as geofoam.
    - Geogrid reinforced embankments.
    - Ground improvement techniques.
    - Surcharge, with or without vertical wick drains.

1.16.2.12 QA/QC, Quality Control for Prefabricated Concrete Elements

1.16.2.12.1 Types

A variety of prefabricated concrete elements have been used on many projects. Prestressed concrete elements have been used since the 1960s. Use of non-prestressed prefabricated

concrete elements dates back even earlier. The types of prefabricated concrete elements used on ODOT projects have included:

- Prestressed slabs and box beams.
- Prestressed girders.
- Prestressed columns.
- Prestressed arch ribs.
- Prestressed piles.
- Bridge railing.
- Bridge approach slabs.
- Pile caps/abutments.
- Stay-in-place deck forms.
- Culverts.
- Manholes and utility vaults.

1.16.2.12.2 Prestressed Elements

When precast concrete elements include prestressing, *SP 00550* of the standard specifications apply. *SP 00550.05* requires fabricators to be certified under the PCI Plant Certification Program. PCI certification ensures that industry best practices are followed. The member tolerances specified in *SP 00550.04* are those recommended by PCI.

For non-standard prestressed concrete elements, the existing *SP 00550* Oregon Standard Specifications for Construction will likely be adequate without modification. The designer may need to create a unique bid item since the available bid items only cover our current standards.

Verify new or modified details with local precasters (Knife River and R.B. Johnson Co.) before design plans are final. Also confirm with the Structural Materials Engineer whether standard inspection procedures are adequate.

1.16.2.12.3 Non-Prestressed Elements

Specify concrete elements that are not prestressed under *SP 00540*. Since there is not a nationally recognized certification program for non-prestressed elements, determine some minimum qualifications for fabricators. Minimum qualifications may include:

- Submission of a Quality Control Plan.
- Names and qualifications of key personnel.
- History of similar projects.
- Procedure for tracking material certifications.

The nature and complexity of the project will determine which items above should be included in the minimum contractor qualifications. Solicit input from the Structural Materials Engineer before finalizing any contract special provisions.

In addition to project qualifications, it may be desirable to require the contractor to identify the form material and forming details. Lifting and shipping details may also be required. For unique lifting and shipping situations or large elements, it may be necessary to require

verification of lifting and shipping details. Such verification could be achieved with review by a professional engineer or by testing. Especially where there is potential for items to be fabricated by a contractor with little or no experience with precasting concrete, include special provision language to clarify any requirements that ensure safe and adequate lifting and transport details. In some cases, it may be desirable to add lifting and shipping verification as part of the contractor's Quality Control Plan.

Where precast concrete elements are specified under *SP 00540*, a special provision will be needed to address measurement and payment. Most structural concrete is paid on a cubic yard basis. However, precast concrete elements are typically paid either on a per length basis or per each.

Standard fabrication tolerances for structural concrete are provided in *SP 00540.40*. These tolerances are based on typical cast-in-place concrete construction. For precast elements tighter tolerances may be achievable and desirable. Consult with the Structural Materials Engineer to determine reasonable tolerances for your specific application.

Inspection of precast concrete elements is required both during the precasting operation and during placement in the field. The Structural Materials Engineer is responsible for inspection of precast elements and should be notified when precast concrete elements are to be used. This will help ensure ODOT staff is scheduled to be available for such inspections and whether any adjustment to the *ODOT Nonfield-Tested Materials Acceptance Guide* is needed.

1.16.2.12.4 Connection Issues

Current state-of-the art does not support connection of precast cap elements in high seismic locations. This is currently being researched at the national level.

Connection of precast elements may involve the use of grout pockets to emulate cast-in-place construction. Where grout pockets are used, manufacturer's recommendations should be followed regarding when grout should be extended with aggregate. For many grout products, aggregate is recommended when the pocket size reaches 2 inches or more.

1.16.2.13 Cost Considerations

It has been determined by numerous projects nationally that accelerating a project delivery will reduce the costs to highway users associated with traffic queues and detours during the bridge installation. Utah DOT has demonstrated that ABC can be successful and the initial costs of innovation are absorbed on the first few projects when there is some assurance that more projects using the same technology are being planned for the near future. The use of ABC should be justified on a specific project by analyzing the user cost savings compared to the estimated cost of various methods of rapid construction (see HYRISK discussion below).

ODOT has posted a *Work Zone Traffic Analysis Tool* that considers such topics as traffic delays and operations, and long detours. Guidance on Incentive/Disincentive Program for designers is also available.

1.16.2.13.1 Incentive/Disincentive Program

Requirements related to reduced traffic impact and time must be clearly specified in the contract documents. Innovative contracting strategies to achieve accelerated construction include incentive/disincentive, a financial bonus or penalty for delivery before or after a time set in the contract; A+B bidding, cost-plus-time based on the combination of contract bid items (A) and the time bid for construction multiplied by daily user cost (B); lane rentals, assessed rental fees for lanes taken out of service during temporary lane closures for construction; and no-excuse bonus, a modified incentive with no time adjustment for problems such as delays due to weather or utility conflicts regardless of who is responsible.

Incentives and disincentives for early completion give contractors a financial reason to change their conventional practices to accelerate construction. Contractors cannot count on incentives and, therefore, may not reduce their bid price in anticipation of receiving incentives. Disincentives are necessary but may result in higher bid prices because of the risk to contractors that they will not be able to meet the reduced construction timeline. In some accelerated bridge project case studies, it was found that by providing the right incentive/disincentive, contractors were able to lower overall total project costs when compared to conventional delivery methods.

1.16.2.13.2 Maintenance of Traffic Costs

Traffic management and user delay-related costs associated with bridge construction activities will significantly influence the selection of the most cost-effective bridge technology.

Elaborate traffic control plans can significantly add to the cost of replacement, especially when the traffic control plan changes significantly during the project due to development, local expansion, or other projects in the area. Cost savings from the reduced duration of the traffic control plan through the use of ABC method of delivery can be estimated based on the reduced number of days of traffic control cost times the average daily operating cost of such measures for comparable bridge projects.

1.16.2.13.3 Contractor's Operation Costs

In general, contractors bid projects with the plan to complete onsite construction as quickly as possible to increase profits. This is particularly true for projects with incentives for early completion. The contractor's costs, including overhead costs to staff projects, are reduced when the duration of the construction project is reduced. Also, construction crew safety in the work zone is increased with reduced exposure times.

1.16.2.13.4 Owner Agency's Operation Costs

Agency overhead costs to staff projects, e.g., construction engineering and inspection support, are reduced when the duration of construction projects is reduced. Prefabricated bridges, with their rapid onsite installation, can significantly reduce these project costs.

The use of prefabricated bridges to accelerate construction cannot be approached in a conventional manner by the owner. The owner will need to commit to working multiple shifts, odd hours, and under the same constraints as the contractor.

The manufacturers of prefabricated components may be able to offer lower unit costs if they can spread their fixed costs over many bridges or reuse formwork repeatedly. Bundling projects provides an attractive incentive for a contractor to acquire new or special equipment when they can recoup their investment on multiple applications.

1.16.2.13.5 Available Tool: HYRISK

How much will it cost highway users if a bridge is closed or detoured? The bridge with the longer detour requires additional time and mileage costs to negotiate the detour, and incurs the most cost to users. The cost of bridge construction alone fails to capture the total cost of the project.

A method that blends bridge construction cost and the users economic losses associated with a bridge construction is discussed in *Table 1.16.2.13.5-1* using HYRISK algorithm to compute the economic impact to a community.

AADT and detour length are extracted from the NBI record for the bridge. The assumed 2008 cost per distance traveled was equal to $0.44/mi ($0.27/Km). It is assumed that the project would have one year duration of the detour.

Table 1.16.2.13.5-1 HYRISK Matrix

Detour Mileage Cost (DMC) = Duration * Length Detour (L) * Cost/Length (CpL) *ADT Sample Bridge Project (Br # 00138)	
Duration of facility for construction (D) in days	365
Detour length (L) in km	26
Cost per Mile per Vehicle driven of detour length (CpL)/km	$0.27
Annual Average Daily Traffic (AADT)	330
Time cost per person (TcP)/hr	$16.31
Occupancy rate (person) per vehicle (O)	1.56
Time cost per truck (TcT)/hr	$29.50
ADTT (Truck Traffic as a percentage of AADT; i.e. 10 percent this case)	.10
Speed of Traffic on Detour (DS) in km/hr	64
Detour Mileage Cost (DMC) = D*L*CpL*ADT	$845,600
Detour Time Cost (DTC) = D*L*[(O*TcP)*(1-ADTT)+(ADTT*TcT)]	$1.265 M
Total Community Cost associated with bridge closure $T1_{cost}$=DTC+DMC	$2.11 M

1.16.2.14 Listing of bridges replaced using ABC techniques

Contact the BDM Technical Resource for *BDM 1.16.2.14* to request a project be added to the list. Plans for these projects can be found using *BDS (Bridge Data System)*.

Table 1.16.2.14-1 List of Bridges Replaced Using ABC Techniques

BDS Structure Number	Year Built	Region	Project Title	ABC Technique Used
BR22163	2014	5	Whiskey Creek, Wallowa County	PS Slabs on steel pile caps – 2- week road closure.
BR22057	2014	2	US 26 West Humbug Creek Bridge	Used precast and prefabricated elements. Precast deck panels.
BR22105	2014	5	OR 203 Branch of Ladd Creek Culvert	Inverted rigid frames with precast prestressed slabs as top panels, 30-foot spans. Used short bypass 2-lane detour.
BR00711	2013	2	US101B Lewis & Clark River Bridge	Partial ABC with CIP deck. Used some precast and prefabricated elements.
BR21548 BR21549	2012	5	US 26 Dean and Dog Creek Culverts	Inverted rigid frames with precast top slabs to form a single cell box, 16-foot span. Used centerline shoring.
BR21252	2012	5	US30 Burnt River (UPPR)	Precast PS Deck Panels with UHPC joints and connections. Steel diaphragms. FHWA Demo Project for Life Grant.
BR21439	2012	3	Hwy 1 Kane Creek Frtg Road LT (Old Stage Road)	Precast pile caps, end panels and wingwalls.
BR21493	2011	1	Sellwood Bridge, Willamette River	Slide bridge into place using "Shoo Fly" technology. SellwoodBridge.org
BR21188	2010	2	US26 Volmer Creek Bridge	All precast or prefabricated elements (staged construction).
BR21189	2010	2	US26 Johnson Creek Bridge	All precast or prefabricated elements (staged construction).
BR20584 BR20585	2008	3	OR 38 over Elk Creek Bridges near Elkton	1 steel plate, 1 Bulb-T girder bridge built on temporary falsework adjacent to the existing. Skidded on tracks during two weekend road closures.
BR20586	2008	3	OR 38 Bridge over Hardscrabble Creek, Douglas County	Bridge built adjacent to the existing and skidded into place.
BR02398	2008	5	Kimberly Bridge OR19, Grant County	Rapid replacement of 2 approach spans using precast pile caps on a long structure with 20-day full road closure.
BR01132 F	2007	3	Hwy 241 Isthmus Slough (east side)	Constructed substructure around existing bridge.
BR19273	2007	3	Depot Street Bridge over the Rogue River, Jackson County	306-foot concrete arch built adjacent to existing bridge and skidded into place. Road closed for 5 days.
BR20136	2007		Sauvie Island Bridge over Columbia River, Multnomah County	365-foot steel tied arch. SPMT used to skid and load bridge on barges and floated span into place.
	2007	1	OR 47 over Dairy Creek Overflow Bridge, Washington County	Used steel pile cap and reused salvage precast, prestressed slabs. Road closed for 14 days.
BR20238	2006	2	US 20 Bridge over Hayes Creek, Eddyville, Lincoln County	Used precast cap and slabs. Bridge constructed during a 72-hour road closure.
BR00711	2004	WSDOT Lead	Lewis & Clark Deck Replacement	SPMT used to replace superstructure 5478' L X 34" W, 34 panels. Conventional method duration was 4 years. Using ABC, done in 6 months with full road closure.
BR01660	2002	4	OR 26 Mill Creek Bridge Deck Replacement, Wasco County	3-span continuous truss with deck panels. Panels replaced sequentially with partially concrete filled exodermic steel grid deck. 540-foot deck replaced in 24 days under flexible road closure schedule.
BR07333	1997	1	I-5 (Interstate) Bridge over Columbia River, Multnomah County	Accelerated replacement of 2 trunnion assemblies and span/counterweight cables. Contractor awarded $1.4+M incentive ($100K/day) for early completion in less than 7 days; 14 days ahead of the required 21-day schedule.
BR18074	1997	5	Imnaha Bridge over Little Sheep Creek	Single span, concrete-filled grid deck over steel curved girder bridge. Built first half of new bridge and switched traffic over; demolished existing bridge and built second half with skidding to connect the two halves. Longitudinal concrete closure-pour in the middle
BR02529	1973	1	Freemont Bridge over Willamette River, Multnomah County	Arch span was floated on barges and moved into place using strands jacking.
			Sam Jones Bridge	Full depth precast deck panels.

1.16.3 Bridge Temporary Works

1.16.3.1 Design Considerations

C1.16.3.1

Temporary works include any temporary construction used to construct highway related structures but are not incorporated into the final structure.

Temporary works required for construction of permanent structures include:

- Diversion bridge.
- Work bridge.
- Falsework.
- Formwork.
- Shoring.
- Cofferdams.
- Temporary retaining structures.

See *BDM 1.3.4* for temporary loading.

The following tables include common Special Provisions and Standard Specifications.

Table 1.16.3.1-1 Special Provisions

Title	Section Number
Temporary Roadbed and Surfacing	00230
Diversion Bridges	00250
Agency Provided Temporary Bridges	00251
Temporary Work Bridges	00252
Temporary Work Access and Containment	00253
Temporary Bridge Jacking	00255
Temporary Retaining Walls	00256

Table 1.16.3.1-2 Standard Specifications

Title	Section Number
Structure Excavation and Backfill (shoring and cofferdams)	00510
Structural Concrete (Falsework)	00540
Trench Protection	00405.41(f)
Temporary Trench Plating	00405.46(c)
Jacking Pits	00406.41(b)

1.16.3.2 Diversion Bridges

Diversion bridges are bridges with a maximum service life of five years to carry traffic while an existing structure is replaced. Diversion bridges have the same requirements as that of a permanent structure, except as specified in this section.

Design diversion bridges using latest edition *AASHTO LRFD Bridge Design Specifications*. For seismic design requirements, refer to *BDM 1.17.2.1*.

1.16.3.2.1 Hydraulics Requirements

Hydraulic requirements apply to diversion structures designed by ODOT, and those designed by a contractor.

The hydraulics report provides recommendations for the diversion bridge. The data will include seasonal limitations, flow area of the structure, and minimum elevation of the diversion roadway.

Prepare a brief statement about the proposed location of the diversion. Other information about the diversion may include a discussion of maintenance needs such as monitoring for debris or scour. The diversion structure must conform to the temporary water management plan regarding fish passage.

Only use a dry season diversion during the dry season. The hydraulics report defines the start and end of the dry season. The design and check floods are based on the maximum predicted discharges for the months the diversion will be in place. Use the 2-year flood as the minimum design flood event.

An all-year diversion may be used throughout the year. The all-year diversion must pass the 5-year flood event at a minimum. Use the 10-year and 25-year check flows to determine the risk of damage when they occur during the time the diversion is in place.

The minimum road elevations for dry season and all-year diversions are the elevations at which the roadway will not overtop during the 2-year or 5-year flows, respectively. *Section 3.9* of the *ODOT Hydraulics Manual* furnishes more detailed guidance on requirements for either duration detour.

Consider and address other issues, such as maintenance needs, fish passage, navigational clearance, or other site-specific needs.

The crossing of FEMA floodways with temporary structures requires special consideration. Temporary structures must meet additional hydraulic requirements when they are in place across the floodway between November 1 and May 31.

During the design process, contact Region Tech Center staff for assistance as soon as possible when the structure is to cross a floodway during these months.

Section 3.9 of the *ODOT Hydraulics Manual* furnishes more detailed guidance on FEMA policy requirements.

1.16.3.2.2 Structural Requirements

Design all structures on public roads, temporary or permanent, to carry all anticipated loads, and forces. Temporary structures must also resist lateral loads caused by hydraulics, debris, ice, wind and other applied forces when they exist. Design diversion bridges over waterways assuming scour depths and design flood in accordance with *BDM 1.10.5.8*, the *ODOT Hydraulics Manual* and *Hydraulics Report*.

Mechanically connect members of the diversion bridge together. Design mechanical connections with a minimum capacity to resist a load in any direction, including uplift on the stringer, of not less than 500 pounds. Install all associated connections before traffic is allowed to pass beneath the span. All members at a connection need to resist the developed connection force. Design the substructure to resist all applied combined axial and lateral loads and the minimum connection design force.

Contractor designed diversion bridge will follow all required design steps as the design of permanent bridges. Provide necessary data to the contractor in *SP 00250* to accelerate design such as:

- Geotechnical report.
- Hydraulics report.
- Environmental study and limitations.
- In water work window.

Furnish information on the plans not limited to following:

- Minimum structure width, length and number of traffic lanes.
- Permit load (for permit load route).
- Minimum vertical and horizontal clearances when over crossing existing highway.
- All project specific requirements (utilities, sidewalk, railroad, etc.).

1.16.3.2.3 Agency Provided Diversion Bridge

ODOT has one-lane and two-lane diversion bridges ready to erect at different locations. Provide a drawing showing the bridge footprint and foundation drawings.

Use *SP 00251* for these diversion bridges.

C1.16.3.2.3

Contact the Bridge Operations Engineer for availability, scheduling and technical information of these bridges.

1.16.3.3 Falsework

1.16.3.3.1 General

See *BDM 1.3.4.3* for falsework loading.

Temporarily pin concrete barriers that protect falsework from damage from adjacent traffic. Provide at least 1 foot clearance between the barrier and falsework elements.

For falsework spans over roadways and railroads, mechanically connect all falsework stringers to the falsework cap or framing. Install all associated connections before traffic is allowed to pass beneath the span. See *SP 00540.41* for loading.
For falsework over navigable waterways, obtain US Coast Guard (USCG) approvals and permits, as required. Provide details, clearances, requirements and details required by the USCG.

Provide, as a minimum, the following design calculations and detailing of falsework drawings, for a falsework supported by existing columns of a structure for widening projects or maintenance work:

- Complete connection details.
- Location of resin bonded anchors with a note to locate the existing reinforcing prior to drilling holes with GPR or approved equal method.
- Provide note for the contractor to field verify the location of holes prior to connection fabrication when using resin bonded anchor rods or thru holes for bolted connections to support endplates or bracket connections.
- Loading concurrent with *SP 00540*.

C1.16.3.3

C1.16.3.3.1

Refer to *SP 00540.41* and *SP 00540.42* for additional design requirements at highway and railroad traffic openings.

Refer to Caltrans Falsework Manual for more guidance and example problems.

1.16.3.3.2 Bridge Deck Falsework

Do not drill or punch holes through the girder flanges or the web of interior girders for temporary work.

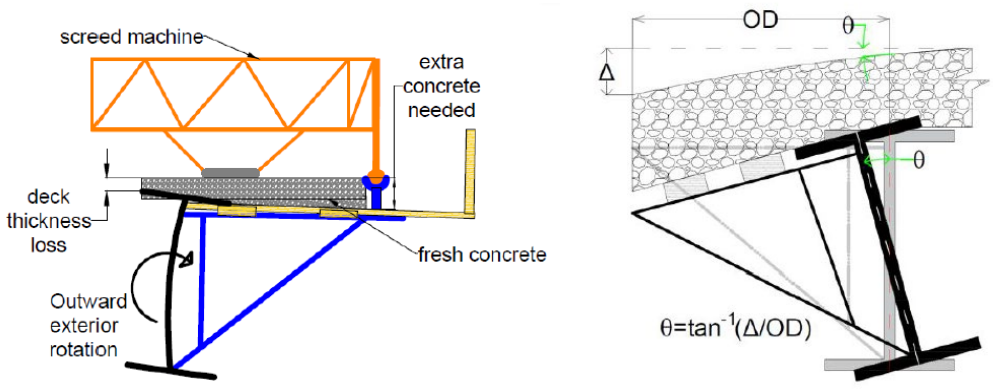
During deck placement operations there is a tendency for exterior girder to laterally deflect and rotate. When the deflection at the overhang tip (Δ) is larger than 3/16 inch, the displacement and rotation can lead to thin decks and an upward shift in bar mats which can decrease concrete cover. The tendency to laterally deflect and rotate is greater for shallow girders with large deck overhang.

C1.16.3.3.2

Deck forms for interior girders are usually set on joists hung on from top flanges or supported by post from bottom flanges. The use of embedded hangers welded to top flanges or shear studs projecting from top flanges is not recommended.

The *AASHTO Construction Handbook for Bridge Temporary Works* has design examples for cantilever deck forming for steel girders and deck overhang brackets.

Figure 1.16.3.3.2-1 Girder Rotation



Horizontal loads applied to the girder flanges by the falsework will produce a torsional moment in the girder. To prevent possible overstressing of the permanent diaphragm connections and distortion on girder web, the falsework design must include temporary struts and ties to resist the full torsional moment and to prevent appreciable relative vertical movement between the edge of deck form and the adjacent steel girder.

Include the following requirements in the specification to control the manner falsework loads are applied to the steel girder, and thus prevent undesirable distortion of the permanent structure.

The contractor is responsible to provide sufficient temporary bracing to minimize lateral deflection and rotation of exterior steel girders during deck placement. Do not assume partially or fully installed permanent bracing as shown in the plans is sufficient to minimize lateral deflection and rotation of exterior girders during deck placement.

Construct falsework and concrete forms on steel structures such that loads applied to girder webs:

- Are applied within 6 inches of a flange or stiffener.
- Do not produce local distortion of the web.
- Provide temporary struts and ties to resist lateral loads applied to girder flanges and prevent appreciable vertical movement between the edge of deck form and the adjacent steel girder.

- Temporary bracing shall not be welded to the steel girders or its attachments including the studs.

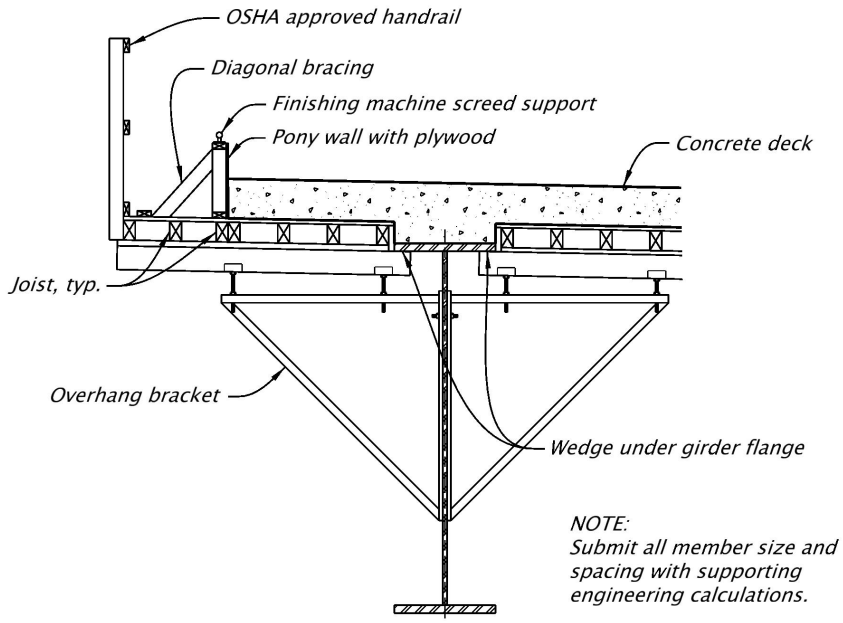
When drilled holes are used to attach the falsework brackets, note the following issues:

- Leaving bolt holes unfilled can reduce the fatigue performance of the member.
- Unfilled holes need subsequent bridge inspection.
- Moisture entrapment and acceleration of main member deterioration due to rust.

When drilled holes are used to attach the falsework brackets, the contractor is responsible to fill the hole with a high-strength *ASTM AF3125* Type 3 fully tensioned bolt, rotational capacity testing not required. The use of button-head twist-off bolts (*ASTM F1852* or *F2280*) is also allowed and may improve the aesthetics.

The contractor may provide double overhang brackets to minimize lock in stresses in exterior girders. *Figure 1.16.3.3.2-2* illustrates typical deck forming details using opposed overhang brackets attached to a steel girder.

Figure 1.16.3.3.2-2 Typical Deck Forming Detail



1.16.3.3.3 Piling

When using piling to support the falsework, the falsework plans shall specify the minimum required bearing capacity and the required depth of penetration for the piling. Provide the field method for determining the required pile bearing capacity.

Also, the falsework drawings shall show the maximum horizontal distance the top of a falsework pile may be pulled in order to position the pile under the cap. The falsework plans shall show the maximum allowable deviation of the top of the pile, in the final position, from a vertical line through the point of fixity of the pile.

The calculations shall account for pile stresses due to combined axial and flexural stress and secondary stresses. Show the stresses and deflections in load supporting members in the design calculations.

1.16.3.3.4 Spread Footings

When spread footings are used to support falsework, the falsework plans shall specify the minimum required bearing capacity, depth of embedment for the footings, and maximum

allowable settlement. Design spread footings to adequately resist all imposed vertical loads and overturning moments.

Provide the soil parameters and groundwater conditions in the design calculations for the spread footings. Provide design calculations for allowable bearing capacity and settlement.

Show the estimated footing settlement under the imposed design loads on the plans. Provide provisions for addressing the effects of footing and falsework settlement.

1.16.3.3.5 Bracing

Do not attach bracing to concrete traffic barrier, guardrail posts, or guardrail.

Design all falsework bracing systems to resist the horizontal design loads in all directions with the falsework in either the loaded or unloaded condition. The falsework plans must show all bracing, connection details, specific locations of connections, and hardware used.

Thoroughly analyze falsework diagonal bracing. Give particular attention to the connections. The allowable stresses in the diagonal braces may be controlled by the joint strength or the compression stability of the diagonal.

Design cross-bracing members and connections to carry tension, as well as compression, to prevent falsework beam or stringer compression flange buckling. The falsework plans must show all components, connection details and specific locations. Install bracing, blocking, struts, and ties required for positive lateral restraint of beam flanges at right angles to the beam in plan view. When possible, set bracing in adjacent bays in the same transverse plane. However, when because of skew or other considerations, it is necessary to offset the bracing in adjacent bays, the offset distance shall not exceed twice the depth of the beam.

Provide bracing to withstand all imposed loads during erection of the falsework and all phases of construction for falsework adjacent to any roadway, sidewalk, or railroad track which is open to the public. Install all details of the falsework system that contribute to horizontal stability and resistance to impact, including the bolts in bracing, at the time each element of the falsework is erected and shall remain in place until the falsework is removed. The falsework plans shall show provisions for any supplemental bracing or methods to be used to conform to this requirement during each phase of erection and removal. Include wind loads in the design of such bracing or methods.

1.16.3.4 Shoring

For structural shoring, see *BDM 1.16.3.3 Falsework*. For the purposes of this manual, shoring is used interchangeably with falsework.

For geotechnical shoring, refer to the *ODOT Geotechnical Design Manual Section 15.3.26* for the design of temporary shoring, and defined shoring systems. Shoring is exclusive of cofferdams.

See *SP 00510.04* for plan requirements. Modify the special provision to include acceptable types of shoring as allowed. Consult with the geotechnical designer to determine safe slopes, minimum shoring lengths, and when there are unusual soil, clearance, or site conditions that may make shoring construction difficult.

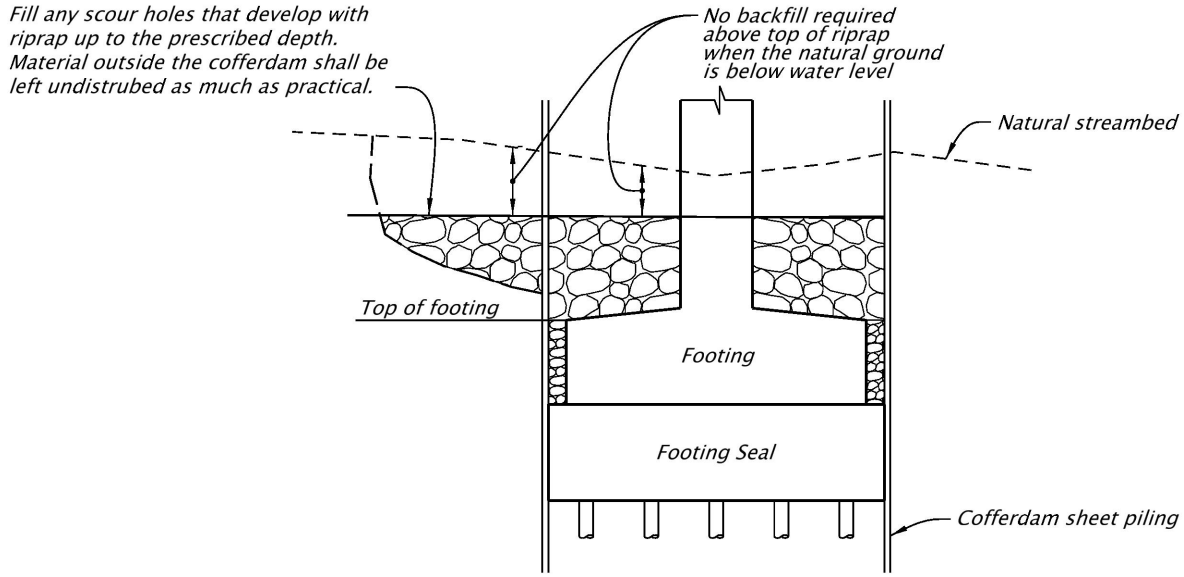
Provide shoring stationing on the project plans and list stationing in the *Special Provision*.

1.16.3.5 Cofferdams

1.16.3.5.1 Earth Pressure

When cofferdams are required and passive earth pressures are assumed in the design, show a detail similar to *Figure 1.16.3.5.1-1* on the plans. Material outside cofferdams should also be undisturbed and backfilled with riprap when disturbed.

Figure 1.16.3.5.1-1 – Typical Cofferdam Detail



1.16.3.5.2 Cofferdam Seals

Only use seals when the sheet piles cannot be driven to sufficient depth to cut off the water pressure.

The sheet piling must penetrate and form a seal in the soil so that there is no water flow under the sheet piling. In practice there will be some water entering the cofferdam. Energy is dissipated as the water flows down around the bottom of the sheet piles. Develop a flow net to determine the actual hydrostatic forces. The equipotential flow lines will show a reduction in the hydrostatic uplift forces. The hydrostatic uplift forces will be resisted by the friction between the soil and the sheet piles and the buoyant weight of the soil plug. Additionally, horizontal hydrostatic forces are present and must be designed for. These are special conditions and require detailed hydraulic and foundation studies.

SEAL DESIGN CONSIDERATIONS

The seal forms a plug at the bottom of the cofferdam. It uses a combination of seal mass and friction between the seal concrete and piling to resist the hydrostatic forces.

Scour protection for the footing influences the location (depth) of the footing and must be incorporated into the design. The Hydraulics Unit provides this information.

The top of the footing should be below the 100-year scour depth and the bottom of footing below the 500-year scour depth. The Hydraulics Unit provides these elevations.

Normally the friction or bond between the seal concrete and steel piling is assumed to be 10 psi for the surface area of the embedded pile. Check with the geotechnical designer for bond values of other pile types.

An uplift capacity of driven piling should also be obtained from the geotechnical designer to include in the overall stability or factor of safety of the system.

The minimum factor of safety of the system should be one. Note: The actual factor of safety is greater because the bond between the seal and sheet piling has been neglected.

A general rule of thumb, or good starting point, for seal thickness is 0.40 times (head of water plus an estimated seal thickness) for spread footings and 0.25 times (head of water plus an estimated seal thickness) for pile supported footings.

Use a minimum depth of seal of four feet, where piles are calculated to resist uplift in order to reduce seal depth.

Design pile footings that includes a seal for bending and shear ignoring any beneficial effects of the seal. This is due to the uncertain quality of the seal concrete and because the seal may be reduced or eliminated during construction.

There are two ways of looking at the cofferdam system when determining the seal thickness. Each should result in the same seal thickness:

- Method 1: Assume there is some leakage around the seal and the actual water level inside the cofferdam is at the top of the seal. Base the hydrostatic uplift force on the depth of water to the top of the seal, but because it is submerged the weight of the seal must be determined using the buoyant weight. There are examples of this design shown in *BDM Appendix A1.16.3.5.2.*
- Method 2: Assume the seal prevents any leakage and the hydrostatic uplift depth is to the bottom of the seal. Use the full weight of the seal to resist the uplift forces.

COFFERDAMS WITHOUT SEALS

There may be some locations and soil types where a seal may not be required for footing and column construction. The normal sequence of construction for a cofferdam without a seal includes:

Water level is the same inside and outside the cofferdam:

- Construct cofferdam - normally driven interlocking steel sheet pile.
- Cut vent holes in the sheet piling. Place vent holes at the maximum design water level elevation and allows water to enter the cofferdam. Cut a vent hole at the design elevation to prevent cofferdam failure.
- Excavate material inside the cofferdam to the bottom of the footing elevation. Excavation may also be done after dewatering, when there is no seal required, when the internal bracing is in place.
- Place internal bracing. Usually horizontal bracing consists of wales, frames, or struts to

resist the horizontal hydrostatic forces.
- Drive footing piles, when required. This may also be done after dewatering and after excavation.

Water is removed from the cofferdam:

- Install continuous pumping system. Cofferdams are never completely watertight and a sump system is normally installed to keep the cofferdam relatively dry.
- Cut piles to the specified elevation, when used.
- Construct footing and column in the dry.

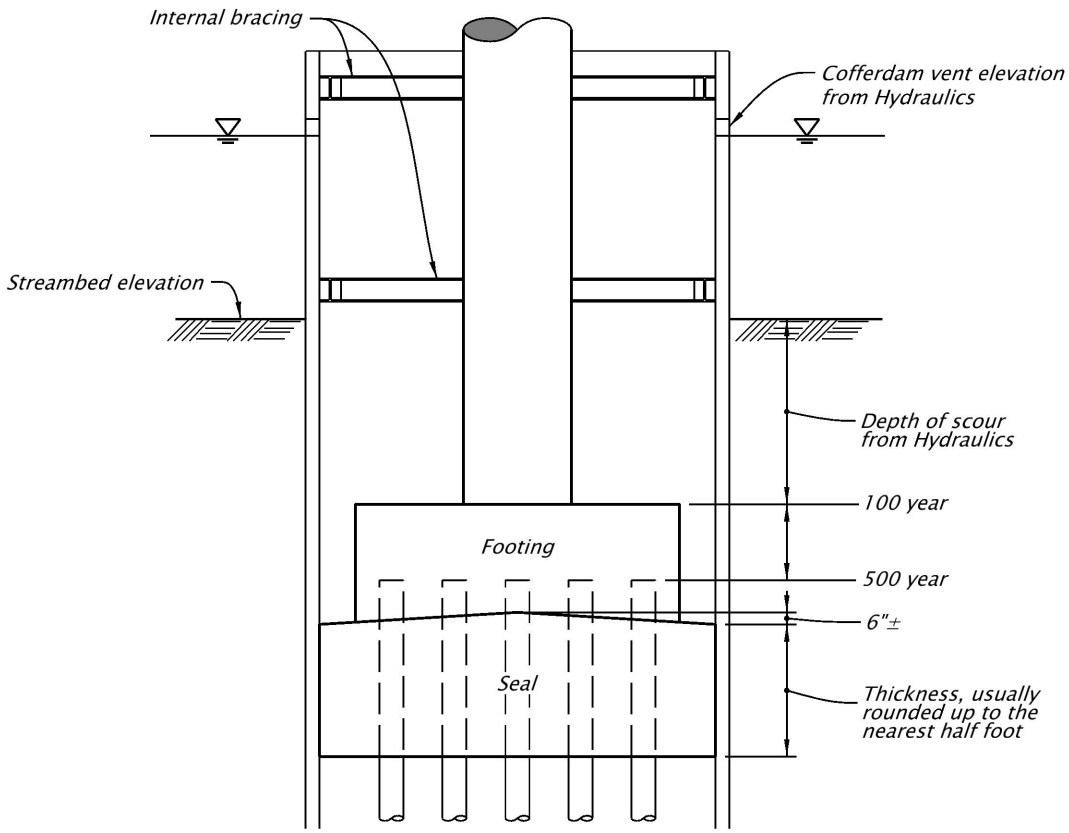
Cofferdam is flooded:

- Remove internal bracing.
- When agreed to by the environmental section, riprap is placed before or after the sheet piling is removed. It may be desirable to place riprap inside the cofferdam. Check with the geotechnical designer.
- Extract sheet piling.

COFFERDAMS WITH A SEAL

A seal is usually an unreinforced mass of concrete that seals the bottom of a cofferdam and allows construction of the footing and column inside of a dewatered or dry cofferdam. (See *Figure 1.16.3.5.2-1*)

Figure 1.16.3.5.2-1 – Seal Thickness Detail



The normal sequence of construction of a cofferdam with a seal depends on water level.

When water level is the same inside and outside the cofferdam:

- Construct cofferdam - normally driven interlocking steel sheet pile.
- Cut vent holes in the sheet piling. Place vent holes at the maximum design water level elevation and allows water to enter the cofferdam. Cut a vent hole at the design elevation to prevent cofferdam failure. The contractor may propose to use a lower vent elevation and thinner seal, when the anticipated water elevation is lower at the time of construction.
- Excavate material inside the cofferdam to the bottom of the seal elevation.
- Place internal bracing. Usually horizontal bracing consists of wales, frames, or struts to resist the horizontal hydrostatic forces.
- Drive footing piles, when required.
- Place seal concrete.
- With a tremie: A tremie is a long pipe that extends to the bottom of the seal and prevents the concrete from segregating as it passes through the water, as well as permitting a head to be maintained on the concrete during placement. The bottom of the tremie is kept submerged in the mass of concrete to minimize water intrusion into the mix.
- With a concrete pump: Similar principle to the tremie.

When water is removed from the cofferdam:

- Dewater cofferdam, only after the concrete has gained sufficient strength to resist hydrostatic loads.
- Install continuous pumping system. Cofferdams are never completely watertight and a sump system is normally installed to keep the cofferdam relatively dry.
- Cut piles to the specified elevation, when used.
- Prepare seal for footing construction. Level and clean, as needed, for constructing footing forms.
- Construct footing and column in the dry.

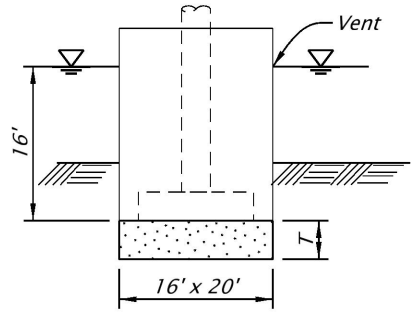
When cofferdam is flooded:

- Remove internal bracing.
- Place rip-rap before or after the sheet piling are removed. It may be desirable to place rip-rap inside the cofferdam. Check with the geotechnical designer.
- Extract sheet piling.

APPENDIX – Section 1.16.3 – Bridge Temporary Works

SPREAD FOOTING EXAMPLE (USING METHOD 1):

Figure A1.16.3.5.2-1 Method 1 Spread Footing



Determine the seal thickness for a 16′ x 20′ cofferdam. Water depth is 16 feet from the vent to the top of the seal.

$$Estimated\ T = 0.4 * (16' + 10' est.thickness) = 10.4'$$

Summing vertical forces:

$Uplift\ force = weight\ of\ water\ displaced$

$Uplift\ force = (Area) * (Depth\ of\ Water) * (Unit\ force\ of\ water)$

$Uplift\ force = (16') * (20') * (16' water\ depth) * (0.0624\ k/ft^3)$

$Force\ of\ seal = buoyant\ force\ of\ the\ seal$

$Force\ of\ seal = (16') * (20') * (T' seal\ thickness) * (0.15\ k/ft^3 - 0.0624\ k/ft^3)$

Uplift force = Force of seal

Solving for T:

$T = 11.4'$

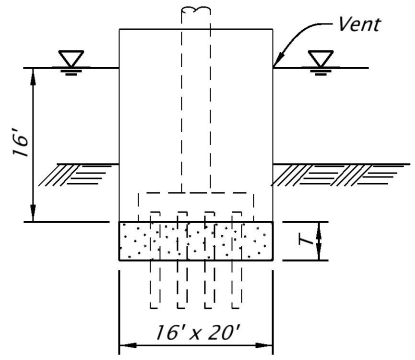
Use 11.5′ seal thickness.

Note: F.S = 1.0 for T = 11.4′

PILE-SUPPORTED EXAMPLE (USING METHOD 1):

Determine the seal thickness for a 16′ x 20′ cofferdam, with 12 – 12″ diameter steel piles. Uplift capacity is 10 kips per pile. Water depth is 16 feet from the vent to the top of the seal.

Figure A1.16.3.5.2-2 Method 1 Pile Supported



$Estimated\ T = 0.25 * (16' + 10' est.thickness) = 6.5'$

Summing vertical forces:

$Uplift\ force = weight\ of\ water\ displaced$

$Uplift\ force = (16') * (20') * (16' water\ depth) * (0.0624\ k/ft^3)$

$Uplift\ force = 319.49k$

$Weight\ of\ seal = buoyant\ force\ of\ the\ seal$

$Weight\ of\ seal = (16') * (20') * (T' seal\ thickness) * (0.15\ k/ft^3 - 0.0624\ k/ft^3)$

$Weight\ of\ seal = 28.03 * (T)\ k/ft$

$Pile\ displaced\ concrete = (12\ pile) * (0.785\ ft^2) * (T') * (0.15 - 0.0624)\ k/ft^3$

$Pile\ displaced\ concrete = 0.825 * (T)\ k/ft$

$Bond\ on\ piles = (12\ pile) * \pi * 1' * 6.5' * 0.010\ ksi * 144\ in^2/ft^2$

$Bond\ on\ piles = 352.86\ k$

$Pile\ uplift\ capacity = (12\ pile) * (10\ k/pile)$

$Pile\ uplift\ capacity = 120\ k < 352.86\ k$

Use 120 k

$Uplift\ force = (Seal\ weight) - (Pile\ disp.conc.) + (Pile\ uplift\ capacity)$

$319.49\ k = 28.03\ (T) - 0.825\ (T) + 120$

Solving for T: $T = 7.33'$

Use 7.5′ seal thickness.

Note: F.S. = 1.0 for T = 7.33′