



2017

LRFD Bridge Construction Specifications

4th Edition



AMERICAN ASSOCIATION
OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS

AASHTO

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Cover photos: **Top:** Erection of the basket handle steel arch of the Edna M. Griffin pedestrian bridge over I-235 in downtown Des Moines, Iowa, during an overnight closure, July 3rd, 2003. Photo provided by Iowa DOT. **Bottom:** Utah South Layton Span 1 over I-15, in Layton, Utah, August 8, 2010. Photo provided by the Utah DOT.

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ABBREVIATED TABLE OF CONTENTS

The *AASHTO LRFD Bridge Construction Specifications*, Fourth Edition, contains the following 33 sections:

1. Structure Excavation and Backfill
2. Removal of Existing Structures
3. Temporary Works
4. Driven Foundation Piles
5. Drilled Shafts
6. Ground Anchors
7. Earth-Retaining Systems
8. Concrete Structures
9. Reinforcing Steel
10. Prestressing
11. Steel Structures
12. Steel Grid Flooring
13. Painting
14. Stone Masonry
15. Concrete Block and Brick Masonry
16. Timber Structures
17. Preservative Treatment of Wood
18. Bearing Devices
19. Bridge Deck Joint Seals
20. Railings
21. Waterproofing
22. Slope Protection
23. Miscellaneous Metal
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25. Steel and Concrete Tunnel Liners
26. Metal Culverts
27. Concrete Culverts
28. Wearing Surfaces
29. Embedment Anchors
30. Thermoplastic Culverts
31. Aluminum Structures
32. Shock Transmission Units
33. Micropiles

FOREWORD

The first broadly recognized national standard to design and construct bridges in the United States was published in 1931 by the American Association of State Highway Officials (AASHO), the predecessor to AASHTO. With the advent of the automobile and the establishment of highway departments in all of the American states dating back to just before the turn of the century, the design, construction, and maintenance of most U.S. bridges was the responsibility of these departments and, more specifically, the chief bridge engineer within each department. It was natural, therefore, that these engineers, acting collectively as the AASHTO Highways Subcommittee on Bridges and Structures, would become the author and guardian of this first bridge standard.

This first publication was entitled *Standard Specifications for Highway Bridges and Incidental Structures*. It quickly became the *de facto* national standard and, as such, was adopted and used by not only the state highway departments but also other bridge-owning authorities and agencies in the United States and abroad. The title was soon revised to *Standard Specifications for Highway Bridges* and new editions were released about every four years. AASHTO released the 17th and final edition in 2002.

The body of knowledge related to the design of highway bridges has grown enormously since 1931 and continues to do so. Theory and practice have evolved greatly, reflecting advances through research in understanding the properties of materials, in improved materials, in more rational and accurate analysis of structural behavior, in the advent of computers and rapidly advancing computer technology, in the study of external events representing particular hazards to bridges such as seismic events and stream scour, and in many other areas. The pace of advances in these areas has accelerated in recent years.

In 1986, the Subcommittee submitted a request to the AASHTO Standing Committee on Research to assess U.S. bridge design specifications, to review foreign design specifications and codes, to consider design philosophies alternative to those underlying the Standard Specifications, and to render recommendations based on these investigations. This work was accomplished under the National Cooperative Highway Research Program (NCHRP), an applied research program directed by the AASHTO Standing Committee on Research and administered on behalf of AASHTO by the Transportation Research Board (TRB). The work was completed in 1987, and, as might be expected with continuing research, the Standard Specifications were found to have discernible gaps, inconsistencies, and even some conflicts. Beyond this, the specification did not reflect or incorporate the most recently developing design philosophy, load-and-resistance factor design (LRFD), a philosophy which has been gaining ground in other areas of structural engineering and in other parts of the world such as Canada and Europe.

From its inception until the early 1970s, the sole design philosophy embedded within the Standard Specifications was one known as working stress design (WSD). WSD establishes allowable stresses as a fraction or percentage of a given material's load-carrying capacity, and requires that calculated design stresses not exceed those allowable stresses. Beginning in the early 1970s, WSD was adjusted to reflect the variable predictability of certain load types, such as vehicular loads and wind forces, through adjusting design factors, a design philosophy referred to as load factor design (LFD).

A further philosophical extension considers the variability in the properties of structural elements, in similar fashion to load variabilities. While considered to a limited extent in LFD, the design philosophy of LRFD takes variability in the behavior of structural elements into account in an explicit manner. LRFD relies on extensive use of statistical methods, but sets forth the results in a manner readily usable by bridge designers and analysts.

AASHTO members include the 50 State Highway or Transportation Departments, the District of Columbia, and Puerto Rico. Each member has one vote. The U.S. Department of Transportation is a non-voting member.

Orders for Specifications may be placed by visiting our website, bookstore.transportation.org, or by calling 1-800-231-3475 (toll free within the U.S. and Canada). A free copy of the current publication catalog can be downloaded from our website or requested from the Publications Sales Office.

The Subcommittee would also like to thank Mr. John M. Kulicki, Ph.D., and his associates at Modjeski and Masters for their valuable assistance in the preparation of these LRFD Specifications.

AASHTO encourages suggestions to improve these specifications. They should be sent to the Chairman, Subcommittee on Bridges and Structures, AASHTO, 444 North Capitol Street, N.W., Suite 249, Washington, DC 20001. Inquiries as to intent or application of the specifications should be sent to the same address.

AASHTO Highways Subcommittee on Bridges and Structures
August 2017

PREFACE

Units

The *AASHTO LRFD Bridge Construction Specifications*, Fourth Edition, uses U.S. Customary units only. Per a decision by the subcommittee in 2009, SI units will no longer be included in this edition or future interims.

References

If a standard is available as a stand-alone publication—for example, the ACI standards—the title is *italicized* in the text and listed in the references. If a standard is available as part of a larger publication—for example, the AASHTO materials specifications—the standard’s title is not italicized and the larger publication—in this case, *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*—is listed in the references.

Unit Abbreviations

Most of the abbreviations commonly used in LRFD Construction are listed below. Also, please note the following:

- Abbreviations for singular and plural are the same.
- Most units of time have one-letter abbreviations. Unit abbreviations are always set in roman type, while variables and factors are set in *italic* type. Thus, “2 h” is the abbreviation for “two hours.”

Table i—Frequently-Used Unit Abbreviations

Unit	Abbreviation
cubic foot	ft ³
cubic inch	in. ³
cubic yard	yd ³
degrees Fahrenheit	°F
foot	ft
foot-kip	ft-kip
foot per hour	ft/h
foot per minute	ft/min
foot per second	ft/s
foot pound	ft · lb
foot pound-force	ft · lbf
foot second	ft · s
gallon	gal
hour	h
Hertz	Hz
inch	in.
joule	J
kilonewton	kN
kilopascal	kPa
kip per foot	kip/ft
kip per square inch	ksi
kip per square foot	kip/ft ²
megapascal	MPa
microinch	μin
micron	μm
mile	mi
minute	min (min. for “minimum”)

Table i (continued)—Frequently-Used Unit Abbreviations

Unit	Abbreviation
newton	N
newton meter	N · m
newton per meter	N/m
ounce	oz
pascal	Pa
pascal second	Pa · s
pound	lb
pound-force	lbf
pound-force foot	lbf · ft
pound-force inch	lbf · in.
pound-force per foot	lbf/ft
pound-force per inch	lbf/in.
pound-force per pound	lbf/lb
pound-force per square foot	psf
pound-force per square inch	psi
pound per cubic foot	lb/ft ³
pound per cubic inch	lb/in. ³
pound per cubic yard	lb/yd ³
pound per foot	lb/ft
pound per inch	lb/in.
pound per hour	lb/h
pound per square foot	lb/ft ²
pound per yard	lb/yd
radian	rad
radian per second	rad/s
quart	qt
second	s
square inch	in. ²
square foot	ft ²
square mile	mi ²
square yard	yd ²
year	yr

Note: There are no abbreviations for *day*, *degree* (angle), *kip*, *mil*, or *ton*.

AASHTO Publications Staff
August 2017

CHANGED AND DELETED ARTICLES, 2016 AND 2017

SUMMARY OF AFFECTED SECTIONS

The fourth edition revisions to the *AASHTO LRFD Bridge Construction Specifications* affect the following sections:

- 3. Temporary Works
- 10. Prestressing
- 11. Steel Structures
- 19. Bridge Deck Joint Seals
- 27. Concrete Culverts

SECTION 3 REVISIONS

Changed Articles

Section 3 has been replaced in its entirety.

SECTION 10 REVISIONS

Changed Articles

The following Articles in Section 10 contain changes or additions to the specifications, the commentary, or both:

10.3.2.3.2

Deleted Articles

No Articles were deleted from Section 10.

SECTION 11 REVISIONS

Changed Articles

The following Articles in Section 11 contain changes or additions to the specifications, the commentary, or both:

11.1.1	11.3.6.2	11.4.9.1	11.5.6.1	11.7.1
11.2.1	11.3.7	11.4.9.3	11.5.6.3	11.7.2
11.3.1.1	11.4.1	11.4.11	11.5.6.4.1	11.8.3.3.1
11.3.1.2	11.4.2	11.4.12.2.1	11.5.6.4.2	11.8.3.4
11.3.1.7	11.4.3.2	11.4.12.2.4	11.5.6.4.3	11.8.3.5
11.3.2.1	11.4.3.3.2	11.4.15	11.5.6.4.4	11.8.3.6.1
11.3.2.6	11.4.3.3.3	11.5.2	11.5.6.4.5	11.8.3.7.1
11.3.3	11.4.6	11.5.3.1	11.5.6.4.6	11.8.5.1
11.3.4.1	11.4.7	11.5.5	11.5.6.4.7	11.8.5.3
11.3.4.2	11.4.8.1.1	11.5.5.1	11.5.6.4.7a	11.8.5.5
11.3.5	11.4.8.1.4	11.5.5.4.1	11.5.6.4.7b	11.10
11.3.5.2	11.4.8.4	11.5.5.4.3	11.6.1	
11.3.6.1	11.4.8.5	11.5.5.4.8b	11.6.5	

Deleted Articles

11.3.1.3	11.3.1.6	11.3.2.4	11.5.6.4.8	11.8.3.4.2
11.3.1.4	11.3.2.2	11.3.2.5	11.5.7	11.8.3.4.3
11.3.1.5	11.3.2.3	11.5.5.3	11.8.3.4.1	11.8.3.6.3

SECTION 19 REVISIONS

Changed Articles

The following Articles in Section 19 contain changes or additions to the specifications, the commentary, or both:

19.2.2	19.3.2	19.4.3.2	19.7
19.3.1	19.4.3.1	19.4.3.3	

Appendix A19

3.1.5	5.1.2	5.3.1.1	5.3.3.2	5.3.4.5
3.1.9	5.1.3	5.3.1.2	5.3.4.2	5.3.5.1
4.1	5.2.2	5.3.2	5.3.4.3	5.3.5.2
5.1.1.4	5.3	5.3.3.1	5.3.4.4	

Deleted Articles

No Articles were deleted from Section 19.

SECTION 27 REVISIONS

Changed Articles

The following Article in Section 27 contains changes or additions to the specifications, the commentary, or both:

27.3.1	27.3.3.3	27.5.2.2	27.9
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Deleted Articles

No Articles were deleted from Section 27.

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STRUCTURE EXCAVATION AND BACKFILL

1.1—GENERAL

C1.1

Structure excavation shall consist of the removal of all material, of whatever nature, necessary for the construction of foundations for bridges, retaining walls, and other major structures, in accordance with the contract documents or as directed by the Engineer.

If not otherwise provided for in the contract, structure excavation shall include the furnishing of all necessary equipment and the construction and subsequent removal of all cofferdams, shoring, and water control systems which may be necessary for the execution of the work.

If not otherwise specified in the contract documents, it shall also include the placement of all necessary backfill, including any necessary stockpiling of excavated material which is to be used in backfill, and the disposing of excavated material which is not required for backfill, in roadway embankments, or as provided for excess and unsuitable material in Subsection 203.02, *AASHTO Guide Specifications for Highway Construction*.

If the contract does not include a separate pay item or items for such work, structure excavation shall include all necessary clearing and grubbing and the removal of existing structures within the area to be excavated.

Classification, if any, of excavation will be indicated in the contract documents and set forth in the proposal.

The removal and disposal of buried natural or man-made objects are included in the class of excavation in which they are located, unless such removal and disposal are included in other items of work. However, in the case of a buried man-made object, the removal and disposal of such object will be paid for as extra work and its volume will not be included in the measured quantity of excavation, if:

- its removal requires the use of methods or equipment not used for other excavation on the project;
- its presence was not indicated in the contract drawings;
- its presence could not have been ascertained by site investigation, including contact with identified utilities within the area; and
- the Contractor so requests in writing prior to its removal.

1.2—WORKING DRAWINGS

Whenever specified in the contract drawings, the Contractor shall provide working drawings, accompanied by calculations where appropriate, of excavation procedures, embankment construction, and backfilling operations. This plan shall show the details of shoring, bracing, slope treatment, or other protective system

Subsection 203.02 is located in the *AASHTO Guide Specifications for Highway Construction*.

proposed for use and shall be accompanied by design calculations and supporting data in sufficient detail to permit an engineering review of the proposed design.

The working drawings for protection from caving shall be submitted sufficiently in advance of proposed use to allow for their review; revision, if needed; and approval without delay to the work.

Working drawings shall be approved by the Engineer prior to performance of the work involved, and such approval shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.

1.3—MATERIALS

C1.3

Material used for backfill shall be free of frozen lumps, wood, or other degradable or hazardous matter and shall be of a grading such that the required compaction can be consistently obtained using the compaction methods selected by the Contractor.

Permeable material for underdrains shall conform to *AASHTO Guide Specifications for Highway Construction*, Subsection 704.01.

Subsection 704.01 is located in the *AASHTO Guide Specifications for Highway Construction*.

1.4—CONSTRUCTION

1.4.1—Depth of Footings

The elevation of the bottoms of footings, as shown in the contract documents, shall be considered as approximate only and the Engineer may order, in writing, such changes in dimensions or elevation of footings as may be necessary to secure a satisfactory foundation.

1.4.2—Foundation Preparation and Control of Water

1.4.2.1—General

Where practical, all substructures shall be constructed in open excavation and, where necessary, the excavation shall be shored, braced, or protected by cofferdams constructed in accordance with the requirements contained in Article 3.3, "Cofferdams and Shoring." When footings can be placed in the dry without the use of cofferdams, backforms may be omitted with the approval of the Engineer and the entire excavation filled with concrete to the required elevation of the top of the footing. The additional concrete required shall be furnished and placed at the expense of the Contractor. Temporary water control systems shall conform to the requirements contained in Article 3.4, "Temporary Water Control Systems."

1.4.2.2—Excavations within Channels

When excavation encroaches upon a live streambed or channel, unless otherwise permitted, no excavation shall be made outside of caissons, cribs, cofferdams, steel piling, or sheeting, and the natural streambed adjacent to the structure shall not be disturbed without permission from the Engineer. If any excavation or dredging is made at the site of the structure before caissons, cribs, or cofferdams are sunk or are in place, the Contractor shall, without extra charge, after the foundation base is in place, backfill all such excavation to the original ground surface or riverbed with material satisfactory to the Engineer. Material temporarily deposited within the flow area of streams from foundation or other excavation shall be removed and the stream flow area freed from obstruction thereby.

1.4.2.3—Foundations on Rock

When a foundation is to rest on rock, the rock shall be freed from all loose material, cleaned, and cut to a firm surface, either level, stepped, or roughened, as may be directed by the Engineer. All seams shall be cleaned out and filled with concrete, mortar, or grout before the footing is placed.

Where blasting is required to reach footing level, any loose, fractured rock caused by overbreak below bearing level shall be removed and replaced with concrete or grouted at the Contractor's expense.

1.4.2.4—Foundations Not on Rock

When a foundation is to rest on an excavated surface other than rock, special care shall be taken not to disturb the bottom of the excavation, and the final removal of the foundation material to grade shall not be made until just before the footing is to be placed.

Where the material below the bottom of footings not supported by piles has been disturbed, it shall be removed and the entire space filled with concrete or other approved material at the Contractor's expense. Under footings supported on piles, the over-excavation or disturbed volumes shall be replaced and compacted as directed by the Engineer.

1.4.2.5—Approval of Foundation

After each excavation is completed, the Contractor shall notify the Engineer that the excavation is ready for inspection and evaluation and no concrete or other footing material shall be placed until the Engineer has approved the depth of the excavation and the character of the foundation material.

1.4.3—Backfill

Backfill material shall conform to the provisions of Article 1.3, “Materials.” If sufficient material of suitable quality is not available from excavation within the project limits, the Contractor shall import such material as directed by the Engineer.

Unless otherwise specified in the contract documents, all spaces excavated and not occupied by abutments, piers, or other permanent work shall be refilled with earth up to the surface of the surrounding ground, with a sufficient allowance for settlement. Except as otherwise provided, all backfill shall be thoroughly compacted to the density of the surrounding ground and its top surface shall be neatly graded. Fill placed around piers shall be deposited on both sides to approximately the same elevation at the same time. Rocks larger than 3.0-in. maximum dimension shall not be placed against the concrete surfaces.

Embankment construction shall conform to the requirements of *AASHTO Guide Specifications for Highway Construction*, Subsection 203.02. The fill at retaining walls, abutments, wingwalls, and all bridge bents in embankment shall be deposited in well-compacted, horizontal layers not to exceed 6.0 in. in thickness and shall be brought up uniformly on all sides of the structure or facility. Backfill within or beneath embankments, within the roadway in excavated areas, or in front of abutments and retaining walls or wingwalls shall be compacted to the same density as required for embankments.

No backfill shall be placed against any concrete structure until permission has been given by the Engineer. The placing of such backfill shall also conform to the requirements of Article 8.15.2, “Earth Loads.” The backfill in front of abutments and wingwalls shall be placed first to prevent the possibility of forward movement. Jetting of the fill behind abutments and wingwalls will not be permitted.

Adequate provision shall be made for the thorough drainage of all backfill. French drains, consisting of at least 2.0 ft³ of permeable material wrapped in filter fabric to prevent clogging and transmission of fines from the backfill, shall be placed at each weep hole.

Backfilling of metal and concrete culverts shall be done in accordance with the requirements of Sections 26, “Metal Culverts,” and 27, “Concrete Culverts.”

C1.4.3

Subsection 203.02 is located in *AASHTO Guide Specifications for Highway Construction*.

1.5—MEASUREMENT AND PAYMENT

1.5.1—Measurement

The quantity to be paid for as structure excavation shall be measured by the cubic yard. The quantities for payment will be determined from limits shown in the contract documents or ordered by the Engineer. No deduction in structure excavation pay quantities will be made where the Contractor does not excavate material which is outside the limits of the actual structure but within the limits of payment for structure excavation.

Unless otherwise specified in the contract documents, pay limits for structure excavation shall be taken as:

- the horizontal limits shall be vertical planes 18.0 in. outside of the neat lines of footings or structures without footings,
- the top limits shall be the original ground or the top of the required grading cross-section, whichever is lower, and
- the lower limits shall be the bottom of the footing or base of structure, or the lower limit of excavation ordered by the Engineer.

When foundations are located within embankments and the specifications require the embankment to be constructed to a specified elevation that is above the bottom of the footing or base of structure prior to construction of the foundation, then such specified elevation will be considered to be the original ground.

When it is necessary, in the opinion of the Engineer, to carry the foundations below the elevations shown in the contract documents, the excavation for the first 3.0 ft of additional depth will be included in the quantity for which payment will be made under this item. Excavation below this additional depth will be paid for as extra work, unless the Contractor states in writing that payment at contract prices is acceptable.

1.5.2—Payment

Unless otherwise provided, structure excavation, measured as provided in Article 1.5.1, “Measurement,” will be paid for by the cubic yard for the kind and class specified in the contract documents.

Payment for structure excavation shall include full compensation for all labor, material, equipment, and other items that may be necessary or convenient to the successful completion of the excavation to the elevation of the bottom of footings or base of structure.

Full compensation for controlling and removing water from excavations and for furnishing and installing or constructing all cofferdams, shoring, and all other facilities necessary to the operations, except concrete seal courses that are shown in the contract documents, and their subsequent removal, shall be considered as included in the contract price for structure excavation, unless the contract document provides for their separate payment.

Unless otherwise specified in the contract documents, the contract price for structure excavation shall include full payment for all handling and storage of excavated materials that are to be used as backfill, including any necessary drying, and the disposal of all surplus or unsuitable excavated materials. Any clearing, grubbing, or structure removal that is required but not paid for under other items of the contract documents will be considered to be included in the price paid for structure excavation.

Unless the contract document provides for its separate payment, the contract price for structure excavation shall

include full compensation for the placing and compacting of structure backfill. The furnishing of backfill material from sources other than excavation will be paid for at the contract unit price for the material being used or as extra work if no unit price has been established.

1.6—REFERENCE

AASHTO. *AASHTO Guide Specifications for Highway Construction*. Ninth Edition. GSH-9. American Association of State Highway and Transportation Officials, Washington, DC, 2008.

SECTION 2: REMOVAL OF EXISTING STRUCTURES

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REMOVAL OF EXISTING STRUCTURES

2.1—DESCRIPTION

This work shall consist of the removal, wholly or in part, and satisfactory disposal or salvage of all bridges, retaining walls, and other major structures that are designated to be removed in the contract documents. Unless otherwise specified, the work also includes any necessary excavation and the backfilling of trenches, holes, or pits that result from such removal. It also includes all costs for environmental and health monitoring systems or programs as may be required.

2.2—WORKING DRAWINGS

Working drawings showing methods and sequence of removal shall be prepared:

- when structures or portions of structure are specified to be removed and salvaged,
- when removal operations will be performed over or adjacent to public traffic or railroad property, or
- when specified in the contract documents.

The working drawings shall be submitted to the Engineer for approval at least ten days prior to the proposed start of removal operations. Removal work shall not begin until the drawings have been approved. Such approval shall not relieve the Contractor of any responsibility under the contract documents for the successful completion of the work.

When salvage is required, the drawings shall clearly indicate the markings proposed to designate individual segments of the structure.

2.3—CONSTRUCTION

2.3.1—General

Except for utilities and other items that the Engineer may direct the Contractor to leave intact, the Contractor shall raze, remove, and dispose of each structure or portion of structure designated to be removed. All concrete and other foundations shall be removed to a depth of at least 2.0 ft below ground elevation or 3.0 ft below subgrade elevation, whichever is lower. Unless otherwise specified in the contract documents, the Contractor has the option to either pull piles or cut them off at a point not less than 2.0 ft below groundline. Cavities left from structure removal shall be backfilled to the level of the surrounding ground and, if within the area of roadway construction, shall be compacted to meet the requirements of the contract documents for embankment.

Explosives shall not be used except at locations and under conditions specified in the contract documents. All blasting shall be completed before the placement of new work.

2.3.2—Salvage

Materials which are designated to be salvaged under the contract documents, either for reuse in the project or for future use by the Owner, shall remain the property of the Owner and shall be carefully removed in transportable sections and stockpiled near the site at a location designated by the Engineer. The Contractor shall restore or replace damaged or destroyed material without additional compensation.

Rivets and bolts that must be removed from steel structures to be salvaged shall be removed by cutting the heads with a chisel, after which they shall be punched or drilled from the hole, or by any other method that will not injure the members for reuse and will meet the approval of the Engineer. Prior to dismantling, all members or sections of steel structures shall be match-marked with paint in accordance with the diagram or plan approved by the Engineer.

All bolts and nails shall be removed from lumber deemed salvageable by the Engineer as part of the salvage of timber structures.

2.3.3—Partial Removal of Structures

When structures are to be widened or modified and only portions of the existing structure are to be removed, these portions shall be removed in such a manner as to leave the remaining structure undamaged and in proper condition for the use contemplated. Methods involving the use of blasting or wrecking balls shall not be used within any span or pier unless the entire span or pier is to be removed. Any damage to the portions remaining in service shall be repaired by the Contractor at the Contractor's expense.

Before beginning concrete removal operations involving the removal of a portion of a monolithic concrete element, a saw cut approximately 1.0 in. deep shall be made to a true line along the limits of removal on all faces of the element that will be visible in the completed work.

Old concrete shall be carefully removed to the lines designated by drilling, chipping, or other methods approved by the Engineer. The surfaces presented as a result of this removal shall be reasonably true and even, with sharp, straight corners that will permit a neat joint with the new construction or be satisfactory for the use contemplated. Where existing reinforcing bars are to extend from the existing structure into new construction, the concrete shall be removed so as to leave the projecting bars clean and undamaged. Where projecting bars are not to extend into the new construction, they shall be cut off flush with the surface of the old concrete.

During full-depth removal of deck concrete over steel beams or girders which are to remain in place, the Contractor shall exercise care so as not to notch, gouge, or distort the top flanges. Any damage shall be repaired at the direction of the Engineer and at the expense of the Contractor. Repairs may include grinding, welding, heat-straightening, or member replacement, depending on the location and severity of the damage.

2.3.4—Disposal

Any material not designated for salvage will belong to the Contractor. Except as provided herein, the Contractor shall store or dispose of such material outside of the right-of-way. If the material is disposed of on private property, the Contractor shall secure written permission from the property owner and shall furnish a copy of each agreement to the Engineer. Waste materials may be disposed of in an Owner's site when such sites are described in the contract documents.

Unless otherwise provided in the contract documents, removed concrete may be buried in adjacent embankments, provided it is broken into pieces which can be readily handled and incorporated into embankments and is placed at a depth of not less than 3.0 ft below finished grade and slope lines. The removed concrete shall not be buried in areas where piling is to be placed or within 10.0 ft of trees, pipelines, poles, buildings, or other permanent objects or structures, unless permitted by the Engineer. Removed concrete may also be disposed of outside the right-of-way as provided above.

The contract documents shall indicate all known hazardous material including paint history. Hazardous material shall be properly disposed of and appropriate records maintained.

2.4—MEASUREMENT AND PAYMENT

The work, as prescribed for by this item, shall be measured as each individual structure or portion of a structure to be removed. Payment will be made on the basis of the lump-sum bid price for the removal of each structure or portion of structure as specified in the contract documents.

The above prices and payments shall be full compensation for all work, labor, tools, equipment, excavation, backfilling, materials, proper disposal, and incidentals necessary to complete the work, including salvaging materials not to be reused in the project when such salvaging is specified and not otherwise paid for.

Full compensation for removing and salvaging materials that are to be reused in the project shall be considered as included in the contract document prices paid for reconstructing, relocating, or resetting the items involved, or in such other contract pay items that may be designated in the contract documents; no additional compensation will be allowed therefore.

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TEMPORARY WORKS

3.1—GENERAL

3.1.1—Description

This work shall consist of the construction and removal of temporary facilities that are generally designed by the Contractor and employed by the Contractor in the execution of the work, and whose failure to perform properly could adversely affect the character of the contract work or endanger the safety of adjacent facilities, property, or the public. Such facilities include but are not limited to falsework, forms and form travelers, cofferdams, shoring, water control systems, and temporary bridges and support structures. Appropriate reductions in allowable stresses and decreases in resistance factors shall be used for design when other than new or undamaged materials are to be used. To the extent possible, calculations shall include adjustments to section properties to account for damage or section loss.

C3.1.1

This Section is revised from the 2010 Third Edition of the *AASHTO LRFD Bridge Construction Specifications*. This Section has been revised to include construction provisions originally found in the *AASHTO Guide Design Specifications for Bridge Temporary Works* which, in turn, has also been revised to contain design provisions only. The organization of this Section remains the same and includes sections on falsework, formwork, cofferdams and shoring, temporary water control systems and temporary bridges. The majority of revisions correspond to the falsework and formwork sections. These documents, the construction and design specifications, complement each other. The *AASHTO Construction Handbook for Bridge Temporary Works* has also been updated and serves as a useful reference for temporary works. The *AASHTO/NSBA Steel Bridge Erection Guide Specification*, the FHWA Publication No. FHWA-HIF-12-013 *Accelerated Bridge Construction—Experience in Design, Fabrication and Erection of Prefabricated Bridge Elements and Systems*, and the *PCI Erector's Manual: Standards and Guidelines for the Erection of Precast Concrete Products* also serve as useful guidelines for bridge construction.

3.1.2—Working Drawings

Whenever specified in the contract documents or requested by the Engineer, the Contractor shall provide working drawings with design calculations and supporting data in sufficient detail to permit a structural review of the proposed design of a temporary work. When concrete is involved, such data shall include the sequence and rate of placement. Sufficient copies shall be furnished to meet the needs of the Engineer and other entities with review authority. The working drawings shall be submitted sufficiently in advance of proposed use to allow for their review, revision, and approval without delay to the work.

The Contractor shall not start the construction of any temporary work for which working drawings are required until the drawings have been approved by the Engineer. Such approval will not relieve the Contractor of responsibility for results obtained by use of these drawings or any of the Contractor's other responsibilities under the contract.

3.1.3—Design

The design of temporary works shall conform to the *AASHTO LRFD Bridge Design Specification* or the *Guide Design Specification for Bridge Temporary Works*, or to another established and generally accepted design code or specification for such work.

C3.1.3

Article 3.1.3 specifies the use of the *AASHTO LRFD Bridge Design Specification* or the *Guide Design Specification for Bridge Temporary Works*, unless another recognized specification is accepted by the Engineer.

When manufactured devices are to be employed, the design shall not result in loads on such devices in excess of the load ratings recommended by their Manufacturer. For equipment where the rated capacity is determined by load testing, the design load shall be as stated in the *Guide Design Specification for Bridge Temporary Works*.

The load rating used for special equipment, such as access scaffolding, may be under the jurisdiction of OSHA and/or other State or Local regulations. However, in no case shall the rating exceed 80 percent of the maximum load sustained during load testing of the equipment.

When required by statute or specified in the contract documents, the design shall be prepared and the drawings signed and sealed by a Licensed Professional Engineer.

3.1.4—Construction

Temporary works shall be constructed in conformance with the approved working drawings. The Contractor shall verify that the quality of the materials and work employed are consistent with that assumed in the design.

3.1.5—Removal

Unless otherwise specified, all temporary works shall be removed at the completion of the project. The area shall be restored to its original or planned condition and cleaned of all debris.

3.2—FALSEWORK

3.2.1—General

The falsework shall be constructed to conform to the falsework drawings. Falsework shall be of sufficient rigidity and strength to safely support all loads imposed and to produce in the finished structure the lines and grades indicated in the contract documents.

Falsework shall be set to grades that allow for anticipated settlement and deflection to occur, and to vertical alignment and camber that are indicated in the contract documents or ordered by the Engineer for the permanent structure.

The working drawings for falsework shall be signed and sealed by a Licensed Professional Engineer whenever the height of falsework exceeds 14.0 ft or whenever traffic, other than workers involved in construction of the bridge, will travel under the bridge.

3.2.2—Foundations

Falsework footings shall bear uniformly on the supporting material, which shall be safe from undermining and protected against softening.

When requested by the Owner, the Contractor shall demonstrate by suitable load tests that the soil-bearing values assumed in the falsework design do not exceed the supporting capacity of the foundation material.

The load-carrying capacity of driven piles, unless driven by a drop hammer, shall be determined by the Gates or other recognized pile driving formula. If a drop hammer

Access scaffolding is covered under the Occupational Safety and Health Administration (OSHA) but stability trusses used for erection of structural steel are designed as falsework.

C3.2.1

Falsework is considered to be any temporary structure which supports structural elements of concrete, steel, masonry or other materials during their construction or erection.

C3.2.2

Surface water from rainfall or other sources could cause scour around foundations, leading to loss of support. The surface water drainage should be diverted to prevent erosion or scour during the time the falsework foundations are in use.

Construction activity taking place in the vicinity of the foundation can alter the foundation support. This can occur when trenches or pits are dug adjacent to the foundation, thereby reducing lateral support of the soil below the foundation level. Heavy construction equipment can cause

is used, the allowable pile capacity shall not exceed the value indicated by the driving formula divided by a factor of safety of 1.5.

rutting that will disturb the soils below the foundation level, thereby weakening them and perhaps leading to unacceptable settlements. Equipment might also be stockpiled next to foundations, causing additional loading that was not considered in the design. All construction activities should be reviewed prior to being implemented so as to maintain the adequacy of the foundation.

Certain soils are susceptible to densification from vibrations and, under the right conditions, may even liquefy. These vibrations can occur from construction related operations such as the driving of piles or sheet piling. Vibrations could also occur from movement of construction equipment across the site. Soil types A, B, and D in Group 3 of Table 2.5 of the *AASHTO Guide Design Specifications for Bridge Temporary Works* are most susceptible to settlement from vibrations.

3.2.3—Timber Construction

Timber beams, stringers, and joists shall be of the size and timber grade specified, and shall be straight and undamaged.

Adequate splice details shall be used where the splicing of timber members is unavoidable. Wherever practical, continuous or overlapping members shall be used.

Where the use of discontinuous members is permitted, joints shall be made over the center of supports. Where a beam comprises a pair of members, joints in the members shall be staggered between supports. Paired members used to form a single beam shall be of identical depth.

3.2.4—Steel Construction

Adequate bracing shall be provided to sections of members in compression and to resist lateral forces applied to the falsework.

Used beams, and particularly beams salvaged from a previous commercial use, shall be carefully examined for loss of section due to welding, rivet or bolt holes, or web openings that may adversely affect the beam's ability to safely carry the imposed load.

C3.2.4

Friction between the joists and the top flange of a steel beam will provide some lateral restraint, but the amount is indeterminate. Therefore, friction between the joists and top flange should be neglected when investigating flange buckling.

Timber cross bracing between adjacent steel beams is commonly used for flange support in falsework construction. In this method, timber struts are set diagonally in pairs between the top flange of one beam and the bottom flange of the adjacent beam, and securely wedged into place. However, timber cross bracing alone will not prevent flange buckling because the timber struts resist only compression forces. A more effective flange support method uses steel tension ties welded, clamped, or otherwise secured across the top and bottom of adjacent beams in combination with timber cross bracing between the beams.

When beams are continuous over two or more spans of unequal length, and if an end span is considerably shorter than the adjacent span, beam uplift may occur at the end of the short span. This uplift condition (negative deflection at the end support) is an indication of system instability and must be considered in the analysis. If theoretical uplift cannot be prevented by loading the short span first, the end of the beam must be tied down or the span lengths changed.

3.2.5—Proprietary Shoring Systems

Proprietary shoring systems shall be undamaged and assembled using only the components supplied by the manufacturer for the particular system.

Proprietary systems shall be installed in accordance with the manufacturer's recommendations, with provision for vertical adjustment.

Extension tubes shall be braced as required and erection tolerances shall not exceed the tolerances recommended by the manufacturer.

3.2.6—Manufactured Components

When manufactured components are used in the falsework, the Owner shall be furnished with a letter of certification signed by the supplier of the component or his authorized representative. The letter of certification shall state that the component is being used in accordance with the manufacturer's recommendations for loads and conditions of use.

3.2.7—Noncommercial Components

If the falsework construction incorporates generic or homemade components fabricated from steel or timber, such as overhang brackets, beam supports, and similar devices, the Owner may require a load test to establish the safe load-carrying capacity of such a component. Such tests shall be performed in the field, on components randomly selected by the Owner, under conditions that will simulate the intended use in the falsework. The allowable capacity of any such component shall not exceed 40 percent of the ultimate load-carrying capacity as indicated by the load test.

3.2.8—Traffic Openings (Clearances)

Unless otherwise provided, the minimum dimensions of clear openings to be provided through falsework for roadways that are to remain open to traffic during construction shall be at least 5.0 ft greater than the width of the approach traveled way, measured between barriers when used. The minimum vertical clearance over interstate routes and freeways shall be 14.5 ft, and 14.0 ft over other classes of roadways.

Falsework at traffic openings shall be protected by a temporary concrete barrier system. The falsework shall be constructed so as to provide clear distances of at least 3.0 in. between the pinned barrier and the falsework footing and at least 1.0 ft between the barrier and all other falsework members. For unpinned barrier provide clear distances of at least 2.0 ft between the barrier and the falsework footing and 2.75 ft between the barrier and all other falsework members.

Temporary bracing required pursuant to the provisions in Section 2.3.7 of the *AASHTO Guide Design Specifications for Bridge Temporary Works* shall be installed concurrently with the restrained element of the falsework system.

C3.2.8

The clearances from falsework over traffic cited in this Section are minimums based on Article 2.3.3 of the *AASHTO LRFD Bridge Design Specifications*. Some states routinely specify greater clearances, that is, vertical clearances of 15.0 ft over freeways and truck routes, and horizontal clearances to include nominal shoulders. Increased horizontal clearances should be specified when indicated by traffic needs or existing roadway geometries at specific sites. Temporary barriers or railings to protect the falsework from vehicular impacts are normally required at all locations except where traffic speeds and volumes are very low.

For falsework over or adjacent to a traffic opening, all details that contribute to horizontal stability and resistance to impact, except bolts in bracing, shall be installed at the time each element of the falsework is erected and shall remain in place until the falsework is removed.

3.2.9—Adjustments

Suitable screw jacks, pairs of wedges, or other devices shall be used at each post to:

- adjust falsework to grade
- permit minor adjustments during the placement of concrete or structural steel should observed settlements deviate from those anticipated, and
- allow for the gradual release of the falsework

The Contractor shall provide for accurate measurement of falsework settlement during the placing and curing of the concrete.

3.2.9.1—Wedges

Wedges shall be installed in sets of two wedges (matched pair) except that a single wedge may be used on a sloping surface. Wedges shall have a height not exceeding one-third of their length. When installed, wedge sets shall be in contact over at least half of their sloping faces.

Wedges may be used at either the top or bottom of a post or strut, but not at both ends.

3.2.9.2—Jacks

Screw jacks shall not be extended beyond the limit set by the manufacturer.

Where hydraulic jacks are used for adjustment, the load imposed by the supported member shall be transferred at the end of the adjustment cycle to a permanent means of support capable of resisting the load without additional settlement or distortion.

Where sand jacks are used, the annular distance between the confining element of the jack and the edge of the base plate shall not exceed 0.25 in.

3.2.10—Camber Strips

When directed by the Owner, camber strips shall be furnished and installed to compensate for beam deflection, vertical alignment, and anticipated structure deflection.

For cast-in-place concrete structures, the calculated deflection of falsework flexural members shall not exceed 1/240 of their span irrespective of the fact that the deflection may be compensated for by camber strips.

3.2.11—Loading

Control of the sequence and rate of placing of concrete shall be exercised to minimize unbalanced load conditions. The concrete shall also be discharged onto the formwork in a manner that prevents overloading.

3.2.12—Removal of Falsework

Unless otherwise specified or approved, falsework shall be released before the railings, copings, or barriers are placed for all types of bridges. For arch bridges, the time of falsework release relative to the construction of elements of the bridge above the arch shall be as shown on the plans or directed by the Engineer.

Falsework supporting any span of a continuous or rigid frame bridge shall not be released until the compressive strength requirements have been satisfied for all of the structural concrete in that span and in the adjacent spans over a length equal to at least one-half the length of the span where falsework is to be removed.

For post-tensioned concrete bridges, the falsework supports that might continue to remain engaged after structural units are prestressed shall be released in such a manner as to permit the concrete to accept its own weight and distribute stresses gradually. Sequence of disengagements shall be such that fixed connections at tops of piers will not be subjected to damaging forces. Sequence of falsework support disengagement shall be shown on falsework drawings.

3.2.13—Dismantling

The falsework shall be designed with due regard for ease and safety of dismantling. Suitable adjustment devices shall be provided for alignment of the falsework during erection, and to facilitate dismantling. Sections of the falsework that are to be shifted and reused without dismantling shall be designed to resist the forces imposed on the falsework during moving operations.

3.3—FORMWORK

3.3.1—General

Forms shall be of wood, steel, or other approved material and shall be mortar tight and of sufficient rigidity to prevent objectional distortion of the formed concrete surface caused by pressure of the concrete and other loads incidental to the construction operations.

Forms for concrete surfaces exposed to view shall produce a smooth surface of uniform texture and color substantially equal to that which would be obtained with the use of plywood conforming to the National Institute of Standards and Technology Product Standard PS 1 for Exterior B-B Class I Plywood. Panels lining such forms shall be arranged so that the joint lines form a symmetrical pattern conforming to the general lines of the structure. The same type of form-lining material shall be used throughout each element of a structure. Such forms shall be sufficiently rigid so that the undulation of the concrete surface shall not exceed 0.125 in. when checked with a 5.0 ft straightedge or template. All sharp corners shall be filleted with approximately 0.75 in. chamfer strips.

Concrete shall not be deposited in the forms until all work connected with constructing the forms has been completed, all debris has been removed, all materials to be embedded in the concrete have been placed for the unit to

C3.2.12

In general, all elements of the falsework system must remain in place for a specified time period or until the concrete attains a specified strength or, in the case of cast-in-place prestressed construction, until stressing is completed. However, these limitations do not apply to bracing, including cable bracing which is installed to prevent overturning or collapse of the falsework system. Such bracing may be removed on the day following concrete placement in any case where the in-place concrete provides horizontal stability. Note that the concrete will provide horizontal stability if, in the Engineer's judgment, it is capable of transferring horizontal forces from the falsework to previously constructed elements of the bridge superstructure.

C3.3.1

Forms are considered to be the enclosures or panels which contain the fluid concrete and withstand the forces due to its placement and consolidation. Forms may in turn be supported on falsework.

Form travelers, as used in segmental cantilever construction, are considered to be a combination of falsework and forms.

Forms for concrete structures using plywood refers to the National Institute of Standards and Technology Voluntary Product Standards PS 1-09, Structural Plywood.



be cast, and the Engineer has inspected the forms and materials.

3.3.2—Tolerances

All formwork shall be built and erected true to line and grade as specified in Contract Documents. Sufficient support systems shall be designed to maintain formwork alignment during construction.

Unless specified in the Contract Documents, the formwork shall be constructed to conform to the tolerance limits of *Standard Specifications for Tolerances for Concrete Construction and Materials* (ACI 117). The class of surface shall also be specified in accordance with ACI 117 document.

Formwork shall be inspected by the Contractor in the presence of the Engineer prior to placement of concrete. Such inspection does not relieve the Contractor of the responsibility of obtaining a concrete structure and finish within the specified tolerances, free of warping, bulging, or other defects. In the event of a defect, the repair method, including removal and replacement, shall be approved by the Engineer and shall be completed at the Contractor's expense.

C3.3.2

Dimensional tolerances for cast-in-place concrete structures prescribed by ACI 117 are as follows:

- Departure from established alignment.....1.0 in.
- Departure from established grades.....1.0 in.
- Variation from the plumb or the specified batter in the lines and surface of columns, piers, walls, and arrises
Exposed, in 10.0 ft.....0.5 in.
Backfilled, in 10.0 ft.....1.0 in.
- Variations from the level or the grades indicated on the drawings in slabs, beams, horizontal grooves, and railing offsets
Exposed, in 10.0 ft.....0.5 in.
Backfilled in 10.0 ft.....1.0 in.
- Variation in cross-sectional dimensions of columns, piers, slabs, walls, beams, and similar parts
Minus.....0.25 in.
Plus.....0.5 in.
- Variation in thickness of bridge slabs
Minus.....0.125 in.
Plus.....0.25 in.
- Variation in the sizes and locations of the slab and wall openings.....0.5 in.

ACI Committee 347 defines four classes of formed surfaces, as shown in Table C3.2-1. Class A is suggested for surfaces prominently exposed to public view, where appearance is of special importance. Class B is intended for coarse-textured concrete formed surfaces intended to receive plaster, stucco, or wainscoting. Class C is a general standard for permanently exposed surfaces where other finishes are not specified. Class D is a minimum quality requirement for surfaces where roughness is not objectionable, usually applied where surfaces will be permanently concealed.

Table C3.2-1—Permitted Irregularities in Formed Surfaces (Checked with a 5.0 ft Template)

Type of Irregularity	Class of Surface			
	A	B	C	D
Gradual	0.125 in.	0.25 in.	0.5 in.	1.0 in.
Abrupt	0.125 in.	0.25 in.	0.25 in.	1.0 in.

3.3.3—Joints

Expansion joints, construction joints, and isolation joints shall be located as shown on the Contract Documents. The location of joints that become necessary due to equipment break down or other interruption must be approved by the Engineer.

Concrete shall be placed continuously from joint to joint. Reinforcement shall pass through construction joints or shall be connected at the joints with mechanical splices. Keyways, when required, shall be formed to assure a full keyway and accurate alignment.

Bulkheads shall be adequate to support the lateral concrete pressures without visible movement during concreting operations. The concrete shall be vibrated at the bulkhead joint to assure good consolidation of the concrete at the joint.

Expansion joints shall be constructed to permit free movement. Projections of concrete into the joint that are likely to spall under movement or prevent the proper operation of the joint are to be carefully removed.

3.3.4—Form Accessories

Metal ties or anchorages utilized to maintain formwork in proper alignment shall be manufactured to permit removal or breakback to a depth of at least 1.0 in. from the face of the concrete without damage to the concrete. The cavities created shall be filled entirely with a cementitious mortar. Where removable through ties are utilized, the cavity created shall be constructed so as to minimize the area. The cavities shall be filled entirely with a cementitious mortar.

The working components coil rod, bolts, or other fastening mechanisms shall have the ends that are to be encased in concrete greased or oiled to provide easy removal. All reused parts shall be thoroughly inspected for straightness, thread wear, and other types of damage.

When epoxy-coated reinforcing steel is required, all metal ties, anchorages, or spreaders that remain in the concrete shall be of corrosion-resistant material or coated with dielectric material.

3.3.5—Prefabricated Formwork

The requirements for prefabricated forms, regardless of material type, are the same as required for standard formwork including design, strength, mortar tightness, chamfers, filleted corners, bracing, alignment, oiling, and reuse. The sheathing shall be of such strength that it remains true to shape and alignment. All bolted and riveted heads shall be countersunk on the face of the form.

3.3.6—Stay-in-place Forms

Stay-in-place deck soffit forms, such as corrugated metal or precast concrete panels, may be used if shown in the contract documents or approved by the Engineer. Prior to the use of such forms, the Contractor shall provide a complete set of details to the Engineer for review and approval. Unless otherwise noted, the Contract Documents

C3.3.3

In continuous bridges, with center spans that exceed 150 ft, the positive and negative moment areas should be poured separately, with a transverse construction joint located near the point of dead load contraflexure. The placing sequence should be determined on an individual basis and shown on the Contract Documents. Positive moment regions should be placed first to avoid separation of the deck at the construction joint and to limit deck cracking in the negative moment region.

On wide bridges, a longitudinal bonded construction joint may be placed at the edge of an intermediate traffic lane. Placement of a joint within a traffic lane should be avoided. The joint should be located within the center half of the deck slab.

for structures are dimensioned for the use of removable forms. Any changes necessary to accommodate stay-in-place forms, if approved, shall be at the expense of the Contractor.

Form sheets shall not be permitted to rest directly on top of the stringer or floor beam flanges. Sheets shall be securely fastened to form supports and shall have a minimum bearing length of 1.0 in. at each end. Form supports shall be placed in direct contact with the flanges of stringers and floor beams. All attachments shall be made by permissible welds, bolts, clips, or other approved means. However, arc strikes and welding of form supports to flanges shall not be permitted. Welding and welds shall be in accordance with the provisions of AWS D1.1/D1.1M.

Any permanently exposed form metal where the galvanized coating has been damaged shall be thoroughly cleaned, wire-brushed, and painted with two coats of zinc oxide-zinc dust primer, Federal Specification TT-P-641d, Type II, no color added, to the satisfaction of the Engineer. Minor head discoloration in areas of welds need not be touched up.

Transverse construction joints shall be located at the bottom of a flute and 0.25 in. weep holes shall be field-drilled at not less than 12.0 in. on center along the line of the joint. Joint and weep holes shall be located at the lowest portion of the concrete soffit.

3.3.7—Tube Forms

Tubes used as forms to produce voids in concrete slabs shall be properly designed and fabricated or otherwise treated to make the outside surface waterproof. Prior to concrete placement, such tubes shall be protected from the weather and stored and installed by methods that prevent distortion or damage. The ends of tube forms shall be covered with caps that shall be made mortar tight and waterproof. If wood or other material that expands when moist is used for capping tubes, a premolded rubber joint filler 0.25 in. in thickness shall be used around the perimeter of the caps to permit expansion. A polyvinyl chloride (PVC) vent tube shall be provided near each end of each tube. These vents shall be constructed to provide positive venting of the voids. After exterior form removal, the vent tube shall be trimmed to within 0.5 in. of the bottom surface of the finished concrete.

Anchors and ties for tube forms shall be adequate to prevent displacement of the tubes during concrete placement.

3.3.8—Bracing and Guying

Forms for walls or columns shall be guyed, shored, or braced to resist wind loads and to withstand alignment shifts resulting from construction live loads. Single-sided bracing shall be designed to withstand tension and compression forces. Wales and other form members shall be designed to transmit accumulated horizontal forces to strut bracing.

3.3.9—Removal of Forms**C3.3.9**

Formwork removal is generally specified in terms of concrete maturity or concrete strength, or a combination of both. ACI Committee 347 recommends the following with respect to time of stripping bridge formwork and its supports.

Shoring and centering removal: should follow recommended practices in Sections 3.5 and 3.7 (see committee report). In no case should supporting forms and shores be removed from horizontal members before concrete strength is at least 70 percent of design strength, as determined by field-cured cylinders or other approved methods, unless removal has been approved by the Engineer. In continuous structures, support should not be released in any span until the first and second adjoining spans on each side have reached the specified strength.

Form removal: forms for ornamental work, railings, parapets, and vertical surfaces that require a surface finishing operation should be removed not less than 12 hours, nor more than 48 hours, after casting the concrete, depending on weather conditions. Bulkheads at construction joints should not be removed for a period of 15 hours after casting adjacent concrete. Forms under slab spans, beams, girders, and brackets should not be removed until the concrete has attained at least 70 percent of its design strength.

3.3.9.1—General

Forms shall not be removed without approval of the Engineer. In the determination of the time for the removal of forms, consideration shall be given to the location and character of the structure, the weather, the materials used in the mix, and other conditions influencing the early strength of the concrete.

Methods of removal likely to cause overstressing of the concrete or damage to its surface shall not be used. Supports shall be removed in such a manner as to permit the structure to uniformly and gradually take the stresses due to its own weight. For arch structures, the sequence of falsework release shall be as specified or approved.

3.3.9.2—Time of Removal

When field operations are controlled by compressive strength tests, the removal of supporting forms or falsework shall not begin until the concrete is found to have the specified compressive strength, provided further that in no case shall supports be removed in less than 7 days after placing the concrete.

If field operations are not controlled by flexural or compressive tests, the following minimum periods of time, exclusive of days when the average temperature is below 40°F, shall have elapsed after placement of concrete before falsework is released or forms are removed:

Not supporting the dead weight of the
concrete.....24 hours

For interior cells of box girders and for railings.....12 hours

If high early strength is obtained by the use of Type III or additional cement in the concrete mix, these periods may be reduced as permitted by the Engineer.

Forms shall not be removed until the concrete has sufficient strength to prevent damage to the surface.

3.3.10—Reuse of Forms

Forms and form material may be reused after they have been inspected for damage. Damaged material shall be discarded or reconditioned. All material reused shall meet the requirements of forms regarding design, strength, mortar tightness, and alignment.

3.4—COFFERDAMS AND SHORING

3.4.1—General

Cofferdams shall be constructed to adequate depths to assure stability and to adequate heights to seal off all water. They shall be safely designed and constructed and be made as watertight as is necessary for the proper performance of the work which is to be done inside them. In general, the interior dimensions of cofferdams shall be such as to give sufficient clearance for the construction of forms and the inspection of their exteriors, and to permit pumping from outside the forms. Cofferdams that are tilted or moved laterally during the process of sinking shall be righted, reset, or enlarged so as to provide the necessary clearance. This shall be solely at the expense of the Contractor.

The Contractor shall control the ingress of water so that footing concrete can be placed in the dry. The Contractor shall determine if a seal is required, and, if required, shall determine the depth of the seal and the cure time required and shall be fully responsible for the performance of the seal. After the seal has cured, the cofferdam shall be pumped out and the balance of the masonry placed in the dry. When weighted cofferdams are employed and the weight is utilized to partially overcome the hydrostatic pressure acting against the bottom of the foundation seal, special anchorages such as dowels or keys shall be provided to transfer the entire weight of the cofferdam into the foundation seal. During the placing and curing of a foundation seal, the elevation of the water inside the cofferdam shall be controlled to prevent any flow through the seal and, if the cofferdam is to remain in place, it shall be vented or ported at or below low-water level.

Shoring shall be adequate to support all loads imposed and shall comply with any applicable safety regulations.

C3.4.1

Cofferdams and shoring consist of those structures used to temporarily hold the surrounding earth and water out of excavations and to protect adjacent property and facilities during construction of the permanent work.

A concrete seal conforming to the requirements of Section 8, "Concrete Structures," shall be placed under water below the elevation of the footing.

3.4.2—Protection of Concrete

Cofferdams shall be constructed so as to protect green concrete against damage from sudden fluctuations in water level and to prevent damage to the foundation by erosion. No struts or braces shall be used in cofferdams or shoring systems in such a way as to extend into or through the permanent work, without written permission from the Engineer.

3.4.3—Removal

Unless otherwise provided or approved, cofferdams and shoring with all sheeting and bracing shall be removed after the completion of the substructure, with care being taken not to disturb or otherwise injure the finished work.

3.5—TEMPORARY WATER CONTROL SYSTEMS

3.5.1—General

Temporary water control systems consist of dikes, bypass channels, flumes and other surface water diversion works, cut-off walls, and pumping systems, including wellpoint and deep well systems, used to prevent water from entering excavations for structures.

3.5.2—Working Drawings

Working drawings for temporary water control systems, when required, shall include details of the design and the equipment, operating procedures to be employed, and location of point or points of discharge. The design and operation shall conform to all applicable water pollution and erosion control requirements.

3.5.3—Operations

Pumping from the interior of any foundation enclosure shall be done in such manner as to preclude the possibility of the movement of water through any fresh concrete. No pumping will be permitted during the placing of concrete or for a period of at least 24 hours thereafter, unless it is done from a suitable sump separated from the concrete work by a watertight wall or other effective means, subject to approval of the Engineer.

Pumping to dewater a sealed cofferdam shall not commence until the seal has set sufficiently to withstand the hydrostatic pressure.

Pumping from wellpoints or deep wells shall be regulated so as to avoid damage by subsidence to adjacent property.

3.6—TEMPORARY BRIDGES

3.6.1—General

Temporary bridges shall be constructed, maintained, and removed in a manner that will not endanger the work or the public.

C3.6.1

Temporary bridges include detour bridges for use by the public, haul road bridges, and other structures, such as conveyor bridges, used by the Contractor.



3.6.2—Detour Bridges

When a design is furnished by the Owner, detour bridges shall be constructed and maintained to conform to either such design or an approved alternative design. When permitted by the Specifications, the Contractor may submit a proposed alternative design. Any alternative design shall be equivalent in all respects to the design and details furnished by the Owner and is subject to approval by the Engineer. The working drawings and design calculations for any alternative design shall be signed by a Licensed Professional Engineer.

When a design is not furnished by the Owner, the Contractor shall prepare the design and furnish working drawings to the Engineer for approval. The design shall provide the clearances, alignment, load capacity, and other design parameters specified or approved in the contract documents. The design shall conform to the *AASHTO LRFD Bridge Design Specifications*. If design live loads are not otherwise specified in the contract documents, HL93 loading shall be used. The working drawings and design calculations shall be signed and sealed by a Licensed Professional Engineer.

3.6.3—Haul Bridges

When haul road bridges or other bridges which are not for public use are proposed for construction over any right-of-way that is open to the public or that is over any railroad, working drawings showing complete design and details, including the maximum loads to be carried, shall be submitted to the Engineer for approval. Such drawings shall be signed by a Licensed Professional Engineer. The design shall conform to *AASHTO LRFD Bridge Design Specifications* when applicable or to other appropriate standards.

3.6.4—Maintenance

The maintenance of temporary bridges for which working drawings are required shall include their replacement in case of partial or complete failure. In case of the Contractor's delay or inadequate progress in making repairs or replacement, the Owner reserves the right to furnish such labor, materials, and supervision of the work as may be necessary to restore the structure for proper movement of traffic. The entire expense of such restoration and repairs shall be considered a part of the cost of the temporary structure and where such expenditures are incurred by the Owner, they shall be charged to the Contractor.

3.7—MEASUREMENT AND PAYMENT

Unless otherwise specified in the Contract Documents, payment for temporary works shall be considered to be included in the payment for the various items of work for which they are used and no separate payment shall be made therefore.

When an item for concrete seals for cofferdams is included in the contract, such concrete will be measured and paid for as provided in Section 8, “Concrete Structures.”

When an item or items for temporary bridges, cofferdams, shoring systems, or water control systems is included in the bid schedule, payment will be the lump-sum bid for each such structure or system which is listed on the bid schedule and which is constructed and removed in accordance with the requirements of the Contract Documents. Such payment includes full compensation for all costs involved with the furnishing of all materials and the construction, maintenance, and removal of such temporary works.

3.8—REFERENCES

American Association of State Highway and Transportation Officials. *Construction Handbook for Bridge Temporary Works*. Second Edition. CHBTW-2. Washington, DC, 2012.

American Association of State Highway and Transportation Officials. *Guide Design Specifications for Bridge Temporary Works*. Second Edition. GSBTW-2. Washington, DC, 2012.

American Association of State Highway and Transportation Officials. *AASHTO LRFD Bridge Construction Specifications*. Third Edition with 2012 Interim Revisions. Washington, DC, 2012.

American Association of State Highway and Transportation Officials. *AASHTO LRFD Bridge Design Specifications*. Eighth Edition. LFRD-8. Washington, DC, 2017.

American Concrete Institute. *Specifications for Tolerances for Concrete Construction and Materials and Commentary*. American Concrete Institute, Detroit, MI, 2006.

American Concrete Institute. *Guide to Formwork for Concrete*. ACI 347-04. ACI Manual of Concrete Practice, Part 3. American Concrete Institute, Detroit, MI, 2011.

American Society of Civil Engineers. *Minimum Design Loads for Buildings and Other Structures*. ASCE 7-10. New York, 2010.

American Society of Civil Engineers. *Design Loads on Structures During Construction*. ASCE 37-02. American Society of Civil Engineers, Reston, VA, 2002.

Duntemann, J. F., L. E. Dunn, S. Gill, R. G. Lukas, and M. D. Kaler. *Guide Standard Specifications for Bridge Temporary Works*. Report No. FHWA-RD-93-031. Federal Highway Administration, Washington, DC, November 1993.

Duntemann, J. F., F. Calabrese, and S. Gill. *Construction Handbook for Bridge Temporary Works*. Report No. FHWA-RD-93-034. Federal Highway Administration, Washington, DC, November 1993.

Duntemann, J. F., N. S. Anderson, and A. Longinow. *Synthesis of Falsework, Formwork, and Scaffolding for Highway Bridge Structures*. Report No. FHWA-RD-91-062. Federal Highway Administration, Washington, DC, November 1991.

National Institute of Standards and Technology and U.S. Department of Commerce. *Structural Plywood*. Voluntary Product Standard PS 1-09. Gaithersburg, MD, 2010.

National Steel Bridge Alliance. *Steel Bridge Erection Guide Specification*. S10.1, Chicago, IL, 2007.

PCI Erectors Committee. *Erector's Manual: Standards and Guidelines for the Erection of Precast Concrete Products*. PCI Committee, Chicago, IL, 1999.

United States Department of Transportation. *Bridge Temporary Works*. Technical Advisory T5140.24. Federal Highway Administration, Washington, DC, October 1993.

United States Department of Transportation. *Certification Program for Bridge Temporary Works*. FHWA-RD-93-033. Federal Highway Administration, Washington, DC, 1993.

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DRIVEN FOUNDATION PILES

4.1—INTRODUCTION

This work shall consist of furnishing and driving foundation piles of the type and dimensions designated in the contract documents, including cutting off or building up foundation piles when required. This Specification also covers providing test piles and performing loading tests. Piling shall conform to and be installed in accordance with these Specifications; at the location; and to the elevation, penetration, and required nominal resistance shown in the contract documents or as directed by the Engineer.

Except when test piles are required, the Contractor shall furnish the piles in accordance with the dimensions shown in the contract documents. When test piles are required, the production pile lengths shown in the contract documents shall be used for estimating purposes only and the actual lengths to be furnished for production piles shall be determined by the Engineer after the test piles have been driven and tested. The lengths given in the order list provided by the Engineer shall include only the lengths anticipated for use in the completed structure. The Contractor shall increase the lengths shown or ordered to provide for fresh heading and for such additional length as may be necessary to suit the method of operation, without added compensation.

C4.1

For the purposes of this document, “nominal resistance” is considered synonymous with “ultimate pile capacity.”

Driven pile lengths are estimated for bidding purposes from soil investigation, static analysis, and perhaps local experience. Rarely, however, are these estimated lengths used to control production pile installations. Usually dynamic methods (e.g., dynamic testing, wave equation, or dynamic formula) are used to evaluate nominal resistance of test piles or the early production piles and then develop a “driving criterion” with a specified number of blows per unit penetration (“blow count”). For larger projects, a static load test is sometimes used to confirm the pile nominal resistance and establish a driving criterion. The blow count criterion determined by the test piles is usually applied to production piles to ensure that they will achieve similar nominal resistances as the test piles. The blow count is in effect an additional quality assurance test.

The objective of this Specification is to provide a criterion by which the Owner can ensure that designated piles are properly installed and the Contractor can expect equitable compensation for work performed. The Owner’s responsibility is to estimate the pile lengths required to safely support the design load. Pile lengths should be estimated based on subsurface explorations, testing, and analysis, which are completed during the design phase. Pile contractors who enter contractual agreements to install piles for an Owner should not be held accountable or indirectly penalized for inaccuracies in estimated lengths. The Contractor’s responsibility is to provide and install designated piles, undamaged, to the requirements specified by the Engineer. This work is usually accomplished within an established framework of restrictions necessary to ensure a “good” pile foundation. The price bid for this item of work will reflect the Contractor’s estimate of both actual cost to perform the work and perceived risk.

4.2—MATERIALS

4.2.1—Steel Piles

4.2.1.1—Rolled Structural Steel Piles

4.2.1.1.1—Specifications for Steel Properties

Steel used in rolled structural steel piles shall conform to the following Standard Specifications of the American Society for Testing and Materials (ASTM):

- ASTM A36/A36M: Standard Specification for Carbon Structural Steel
- ASTM A572/A572M: Standard Specification for High-strength Low-alloy Columbium-vanadium Structural Steel
- ASTM A992/A992M: Standard Specification for Structural Steel Shapes

The above listing does not exclude the use of steel ordered or produced to other than the listed specifications or other published ASTM specifications that establish its properties and suitability.

Steel for cast steel shoes, if used, shall conform to ASTM A148/A148M (Grade 90-60).

4.2.1.1.2—Minimum Dimensions

Sections of such piles shall be of “H” or “W” shape and shall comply with the following requirements:

- The flange projection shall not exceed 14 times the minimum thickness of metal in either the flange or the web, and flange widths shall not be less than 80 percent of the depth of the section.
- The nominal depth in the direction of the web shall not be less than 8.0 in.

Flanges and web shall have a minimum nominal thickness of not less than 0.375 in.

C4.2.1.1.1

A 36/A 36M is not readily available from structural mills. Better economy and availability will be realized by specifying high-strength (50 ksi) ASTM A572/A572M or ASTM A992/A992M.

Pile shoes should be considered when structural steel shapes are driven through obstructions or to sloping hard rock. Pile shoes are discussed in Article 4.4.2.2.2.

4.2.1.2—Steel Pipe Piles

4.2.1.2.1—Specification for Steel

Steel pipe piles shall consist of steel pipe conforming to the project plans.

(a) Minimum Dimensions:

Pipes shall have an outside diameter and a minimum nominal wall thickness as shown in the contract documents.

- (b) Ends of closed-end pipe piles shall be closed with a flat plate or a forged or cast steel conical point, or other end closure of approved design. End plates shall have a minimum thickness of 0.75 in. The end plate shall be cut flush with the outer pile wall. The end of the pipe shall be beveled before welding to the end plate using a partial penetration groove weld.

4.2.1.2.2—Concrete for Concrete-Filled Pipe Piles

Before concrete is placed in the pile, the pile shall be inspected by an acceptable method to confirm the full pile length and dry bottom condition. If accumulations of water in pipes are present, the water shall be removed before the concrete is placed.

The concrete for concrete-filled pipe piles shall have a minimum compressive strength of 2.5 ksi and a slump of not less than 6.0 in. and not more than 10.0 in. Concrete shall be placed in each pile in a continuous operation.

No concrete shall be placed until all driving within a radius of 15.0 ft of the pile has been completed, or all driving within the above limits shall be discontinued until the concrete in the last pile cast has set for at least two days.

C4.2.1.2.1

Open-end pipe piles sometimes are filled and closed-end steel pipe piles are usually filled with concrete as detailed in Article 4.2.1.2.2.

Typically, ASTM A252 Grade 2 is used. However, consideration should be given to using Grade 3, which provides additional strength with little increase in cost. While ASTM A252 is a commonly used specification and performs well in most applications, structures with seismic or special conditions may require additional qualifications. One example of this is as follows: Pipe shall be ASTM A252, but dimensional tolerance as per API 5L and elongation of 25 percent minimum in 2.0 in. The carbon equivalency shall not exceed 0.05 percent. API 5L could be specified, but it requires hydrostatic testing and 48.0 in. outside diameter is the largest diameter covered by API 5L.

Bearing piles are usually of no less than 8.0-in. diameter. Some special applications may have smaller diameters. Generally, wall thicknesses should not be less than 0.188 in. Larger pile diameters generally require larger wall thickness. In some cases, a larger thickness may be desirable for both open-end and closed-end pipe piles. Very thin-wall pipe piles may be difficult to drive in some cases and a thicker wall may be required. Pipes installed open-ended may require a suitable cutting shoe.

Larger diameter pipes may require thicker end plates and/or reinforcement.

C4.2.1.2.2

A drop light or mirror system, downhole camera, or weighted tape with attached dry cloth are possible inspection methods.

It is not necessary to use a tremie or centering cone when placing concrete in pipe piles. It is impossible to center the concrete in a batter pile.

Continuous operation may include changing of concrete supply trucks or other brief interruptions.

4.2.2—Timber Piles

4.2.2.1—General

The Contractor shall supply pressure-treated Southern Pine or Douglas fir piles conforming to ASTM D25, i.e., new and clean peeled one piece from butt to tip. Piles not meeting ASTM D25 requirements shall be rejected.

C4.2.2.1

Timber piles are normally ordered only in 5.0-ft incremental lengths. Usually, Douglas fir piles are available on the west coast, and Southern pine in eastern locations. Southern pine is available up to 80.0 ft in length. Douglas fir piles are available up to 120.0 ft. Most timber piles are 7.0- or 8.0-in. in diameter at the tip. Because of the natural taper of the pile of 1.0-in. diameter reduction for each 10.0 ft of pile length, the butt diameter depends on tip diameter and the pile length. Most commonly available pile sizes are provided in the Timber Piling Council's *Timber Pile Design and Construction Manual*.

4.2.2.2—Submittals

Certification by treating plant stating type, pressure process used, net amount of preservative retained, and compliance with applicable standards shall be submitted to the Engineer. Any structural connections such as for uplift loads shall be shown in the submittal.

4.2.2.3—Field Fabrication

Where specified, timber piles shall be fitted with metal shoes as specified in Article 4.4.2.2.3 of this Specification. If the pile top is trimmed to the final cut-off elevation, cut surfaces at the pile head shall be treated as specified in Article 4.4.7.2.

4.2.2.4—Pressure Treatment

Pressure treatment shall be in accordance with the American Wood Preserver's Association (APWA) Standard U1-06 Use Category System: User Specification for Treated Wood. Category UC4C shall be taken to apply to land and fresh water piling and foundation piling. Categories UC5A, UC5B, and UC5C should generally be taken to apply to timber piling for salt and brackish water application when continuous marine exposure is expected.

4.2.2.5—Required Retentions

The preservative retentions and penetrations provided in the AWP Standard U1-06 Commodity Specifications E and G for the Use Category specified shall apply. The minimum preservative retentions shall be as specified in Table 4.2.2.5-1.

Table 4.2.2.5-1—Preservative Retention Requirements

Use Category	Species ^a	Retention Specifications (lb/ft ³)						
		Creosote CR/CR-S ^b	CR-PS ^b	Pentachlorophenol PCP-A/PCP-C ^b	CuN ^b	ACZA ^b	CCA ^b	ACQ-C ^b
UC4C	Southern pine	12.0	12.0	0.60	0.10	0.80	0.80	0.80
	Coastal Douglas fir	17.0	17.0	0.85	0.14	1.00	1.00 ^a	NR ^b
	Interior Douglas fir	17.0	17.0	0.85	NR ^b	1.00	NR ^b	NR ^b
UC5A	Southern pine	16.0	NR ^b	NR ^b	NR ^b	1.5	1.5	NR ^b
	Coastal Douglas fir	16.0	NR ^b	NR ^b	NR ^b	1.5	NR ^b	NR ^b
UC5B and UC5C	Southern pine	20.0	NR ^b	NR ^b	NR ^b	2.5	2.5	NR ^b
	Coastal Douglas fir	16.0	NR ^b	NR ^b	NR ^b	2.5	NR ^b	NR ^b

Notes:

^a The listing of Coastal Douglas fir as an acceptable species for treatment with CCA is not intended to imply that this species can generally be satisfactorily treated. Treatment for this species is usually satisfactory only if the material is chosen from permeable wood, selected by treatment trials. If treatable wood is not available, the treatment of Coastal Douglas fir with CCA is not recommended.

^b CR/CR-S=Creosote or Creosote Solution; CR-PS = Creosote-Petroleum Solution; PCP-A/PCP-C = Pentachlorophenol, Type A or C Solvent; CuN = Copper Naphthenate; ACZA = Ammoniacal Copper Zinc Arsenate; CCA = Chromated Copper Arsenate; ACQ = Alkali Copper Quat, Type C; NR = not recommended.

4.2.3—Prestressed Concrete Piles**C4.2.3**

Production of piles shall be in accordance with Prestressed Concrete Institute (PCI) MNL-116, *Manual for Quality Control for Plants and Production of Structural Precast Concrete Products*.

For additional information, see the reprint of PCI's "Precast Prestressed Concrete Piles," Chapter 20 of the *PCI Bridge Design Manual* (September 2004), Publication Number BM-20-04.

4.2.3.1—Forms

Forms for prestressed concrete piles shall conform to the general requirements for concrete form work as provided in PCI MNL-116, *Manual for Quality Control for Plants and Production of Structural Precast Concrete Products*.

4.2.3.2—Casting**C4.2.3.2**

Concrete shall be cast continuously within three days after pretensioning steel; however, concrete shall not be cast in forms until placement of reinforcement and anchorages has been inspected and approved by the pile Manufacturer's quality control representative. Each pile shall have dense concrete, straight smooth surfaces, and reinforcement retained in its proper position during fabrication. Unless self-consolidating concrete is used, the concrete shall be compacted by vibrating with a vibrator head smaller than the minimum distance between the pretensioning steel. Ensure that pile end surfaces are perpendicular to the longitudinal axis of the pile.

Continuous casting operation may include changing concrete supply trucks or other brief interruptions.

4.2.3.3—Finish

Finish of piles shall be in accordance with PCI MNL-116, *Manual for Quality Control for Plants and Production of Structural Precast Concrete Products*. Standard finish shall be that the formed sides are reasonably smooth from casting against approved forms. Standard finish of the top shall be a float finish with edges tooled.

4.2.3.4—Curing and Protection

Curing of piles shall be in accordance with PCI MNL-116, *Manual for Quality Control for Plants and Production of Structural Precast Concrete Products*. Piles shall be cured using moist curing or accelerated steam curing.

No pile shall be driven until it is sufficiently cured so as to resist handling and driving stresses without damage.

In cold weather, an extended curing period may be required, as specified in the contract documents. Concrete shall be protected from freezing until the compressive strength reaches at least $0.8 f'_c$.

4.2.3.5—Prestressing

Prestressing of piles shall be in accordance with PCI MNL-116, *Manual for Quality Control for Plants and Production of Structural Precast Concrete Products*.

4.2.3.6—Shop Drawings

The Contractor shall submit the required number of shop drawings for prestressed concrete piles to the Engineer, indicating pile dimensions, materials, tendon arrangement, and prestressing forces proposed for use, and any addition or rearrangement of reinforcing steel from that shown in the contract documents. Construction of the piles shall not begin until the Engineer has approved the drawings.

4.2.3.7—Storage and Handling

Handling, storing, and transporting prestressed concrete piles shall be done in such a manner as to avoid excessive bending stresses, cracking, spalling, or other injurious result.

C4.2.3.3

Special finishes, if required by the Engineer, can be listed here.

C4.2.3.4

Local experience and driving conditions may require longer than seven days' curing time or a minimum concrete strength before driving. Piles driven early may show a higher risk of breakage. If ordered by the Engineer to drive early, the Contractor should not bear the risk of damaged piles.

Air entrainment, water/cement ratio, and type of cement are all important factors in the design of concrete piles for harsh environments. ACI 318-02 Chapter 4, Article 4.3, discusses these issues that contribute to durability in harsh environments such as seawater and sulfate soils.

If exposed to freezing conditions, dowel holes should be protected from water intrusion. For more information on cold weather requirements, refer to PCI MNL-116, *Manual for Quality Control for Plants and Production of Structural Precast Concrete Products*.

C4.2.3.7

Cracks can be repaired, if necessary, by injecting epoxy under pressure into the cracks. Generally recognized guidelines suggest that cracks wider than 0.007 in. can be successfully injected. Smaller cracks often need no repair.