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المملكة العربية السعودية
KINGDOM OF SAUDI ARABIA

اللجنة الوطنية لكود البناء السعودي
Saudi Building Code National Committee

كود البناء السعودي
Saudi Building Code

THE SAUDI CONSTRUCTION CODE

SBC 302 - CR

Code Requirements

2018

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THE SAUDI BUILDING CODE

FOR
CONCRETE CONSTRUCTION

INCLUDING

PART-I. FORMWORK

PART-II CONCRETE WORK

PART III—INSPECTION AND TESTING AGENCIES

(SBC 302-CR)

Key List of the Saudi Codes: Designations and brief titles			
Title	**Code Req.[1]**	**Code & Com.[2]**	**Arabic Prov.[3]**
The General Building Code	SBC 201-CR	SBC 201-CC	SBC 201-AR
Structural – Loading and Forces	SBC 301-CR	SBC 301-CC	SBC 301-AR
Structural – Construction	SBC 302- CR		SBC 302-AR
Structural – Soil and Foundations	SBC 303- CR	SBC 303-CC	SBC 303-AR
Structural – Concrete Structures	SBC 304- CR	SBC 304-CC	SBC 304-AR
Structural – Masonry Structures	SBC 305- CR	SBC 305-CC	SBC 305-AR
Structural – Steel Structures	SBC 306-CR	SBC 306-CC	SBC 306-AR
Electrical Code	SBC 401- CR		SBC 401-AR
Mechanical Code	SBC 501-CR	SBC 501-CC	SBC 501-AR
Energy Conservation- Nonresidential	SBC 601- CR	SBC 601- CC	SBC 601- AR
Energy Conservation-Residential	SBC 602- CR	SBC 602- CC	SBC 602- AR
Plumbing Code	SBC 701- CR	SBC 701-CC	SBC 701-AR
Private sewage Code	SBC 702- CR		SBC 702-AR
Fire Code	SBC 801- CR	SBC 801-CC	SBC 801-AR
Existing Buildings Code	SBC 901- CR	SBC 901-CC	SBC 901-AR
Green Construction Code	SBC 1001- CR	SBC 1001-CC	SBC 1001-AR
Residential Building Code-V1 Arch. Planning and Structural Reqs.	SBC 1101- CR	SBC 1101-CC	SBC 1101-AR
Residential Building Code-V2 MEP, Gas and Energy Requirements	SBC 1102- CR	SBC 1102-CC	SBC 1102-AR

1. **CR: Code Requirements without Commentary**
2. **CC: Code Requirements with Commentary**
3. **AR: Arabic Code Provisions**

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PART III—INSPECTION AND TESTING AGENCIES

(SBC 302-CR)

(Edition 200923)

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PREFACE

The Saudi Building Code for Construction (SBC 302) provides the requirements for the design and safety of formwork, construction requirements for structural concrete, and requirements for agencies engaged in inspection and testing of materials. The entire Code is divided into three parts. The first part (Chapters 1 through 5) of the Code covers the requirements for the design of formwork, the construction loads including dead and live loads and lateral pressure of concrete on forms and environmental loads on formwork. It covers also the construction considerations and safety and inspection requirements. The second part of the Code (Chapters 6 through 11) covers construction requirements for structural concrete including concrete mixtures, production and delivery, handling, placing and finishing, curing of concrete, hot and cold weather concreting. The last part of the Code (Chapters 12 through 14) defines the minimum requirements for agencies engaged in (a) inspection of specified methods and materials used in construction, (b) special inspection, and (c) testing of materials used in construction.

The contents of the current edition of the Code is completely changed from its 2007 edition. Almost all the contents of 2007 edition of SBC 302 has been moved to chapter 17 of SBC 201 and the current edition of SBC 302 is rewritten in 14 chapters. These major changes in the contents of SBC 302 were made to provide all the important requirements related to the construction at one place.

The writing process of SBC 302-18 followed the methodology approved by the Saudi Building Code National Committee. Many changes and modifications were made in the referred sources to meet the local weather, materials, construction and regulatory requirements.

The committees responsible for SBC 302 Code have taken all precautions to avoid ambiguities, omissions, and errors in the document. Despite these efforts, the users of SBC 302 may find information or requirements that may be subject to more than one interpretation or may be incomplete. The SBCNC alone possesses the authority and responsibility for updating, modifying and interpreting the Code.

It is a common assumption that engineering knowledge is a prerequisite in understanding code provisions and requirements; thus, the code is oriented towards individuals who possess the background knowledge to evaluate the significance and limitations of its content and recommendations. They shall be able to determine the applicability of all regulatory limitations before applying the Code and must comply with all applicable laws and regulations.

The requirements related to administration and enforcement of this Code are advisory only. SBCNC and governmental organizations, in charge of enforcing this Code, possess the authority to modify these administrative requirements.

SUMMARY OF CHAPTERS

The entire SBC 302-18 is divided into 3 parts containing 14 chapters. A brief outline of these parts and chapters is given below:

PART-I. FORMWORK—This Part of the Code (Chapter 1 through 5) covers the requirements for the design of formwork, the construction loads including dead and live loads and lateral pressure of concrete on forms and environmental loads on formwork. It covers also the construction considerations and safety and inspection requirements.

Chapter 1. Introduction to Formwork—This chapter provides the definitions of various terminologies used in this part of the Code.

Chapter 2. Design of Formwork—This chapter provides the minimum requirements for the design of formwork. This chapter also covers the design capacity of members; design of shores; manufactured system and components.

Chapter 3. Construction Load—This chapter covers the requirements for construction loads on formwork. It includes dead and live loads, lateral pressure of concrete, wind loads and seismic loads. It includes also shoring and floor loads in multi-story structures.

Chapter 4. Construction Considerations—This chapter provides various regulations pertaining to forming and shoring. The formwork engineers and formwork contractors must follow these regulations to maintain safe conditions for workers and the public.

Chapter 5. Safety and Inspection of Formwork—This chapter provides several requirements related to safety and inspection of formwork. All the requirements are arranged under four main sections: (1) general requirements (2) requirements for equipment and tools, (3) requirements for cast-in-place concrete, and (4) inspection of formwork.

PART-II. CONCRETE—This part of the code (Chapter 6 through Chapter 11) covers construction requirements for structural concrete including concrete mixtures, production and delivery, handling, placing and finishing, curing of concrete, hot and cold weather concreting.

Chapter 6. Scope, Definitions and Referenced Standards—The various terminologies used in part-II (Concrete) of the Code are defined in this chapter. All the Standards, or specific sections thereof, cited in this part of the Code are also listed in this chapter.

Chapter 7. Concrete Mixtures, Production and Delivery—This chapter provides the requirements for materials, proportioning, production, and delivery of concrete.

Chapter 8. Handling, Placing and Finishing—This chapter covers the construction of cast-in-place structural concrete. The chapter also provides procedures for handling, placing, finishing, and repair of surface defects.

Chapter 9. Curing—This chapter provides the requirements for curing the cast-in-place concrete elements including requirements for initiating curing, curing for unformed and formed surfaces, curing time and protection from mechanical injury.

Chapter 10. Hot Weather Concreting—Hot weather is a condition that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration or otherwise causing detrimental results. This chapter provides the requirements for hot weather concrete construction.

Chapter 11. Cold Weather Concreting—Cold weather is an atmospheric condition when for more than three successive days the average daily outdoor temperature drops below 4ºC. This chapter covers requirements for cold weather concreting and protection of concrete from freezing during the specified protection period.

PART-III. INSPECTION AND TESTING AGENCIES—This Part of the Code (Chapter 12 through Chapter 14) defines the minimum requirements for agencies engaged in (a) inspection of specified methods and materials used in construction, (b) special inspection, and (c) testing of materials used in construction.

Chapter 12. General—The definitions of various terminologies and documents referred to in Part-III of the Code are given in this chapter. The chapter also provides requirements for impartial, independent and confidential testing.

Chapter 13. Quality System and Technical Requirements—This chapter covers key factors relevant to an agency's ability to produce precise, accurate test data or determine the conformity of construction activities and materials used in construction with regulations, codes, standards, and approved project plans and specifications containing the requirements against which the inspection or test, or both, will be performed.

Chapter 14. Inspections and Testing of Materials and Construction—This chapter includes scope and specific requirements relating to testing and inspection of various construction types and materials including concrete, soil and rock, steel, sprayed-fire resistive, installed firestops and masonry construction.

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PART I—FORMWORK

CHAPTER 1—INTRODUCTION TO FORMWORK

1.1—Scope

1.1.1 This Part of the Code (Chapter 1 through Chapter 5) covers the requirements for the design of formwork, the construction loads including dead and live loads and lateral pressure of concrete on forms and environmental loads on formwork. It covers also the construction considerations and safety and inspection requirements.

1.2—Definitions

Backshores—Shores placed snugly under a concrete slab or structural member after the original formwork and shores have been removed from a small area at a time, without allowing the slab or structural member to deflect significantly.

Concrete Load—The weight of concrete placed in a form for the permanent structure is a material load. When the concrete gains sufficient strength so that the formwork, shoring, and reshoring are not required for its support, the concrete becomes a dead load.

Construction dead load—The dead load of temporary structures that are in place at the stage of construction being considered. The dead load of the permanent structure, either partially complete or complete, is not included in the construction dead load.

Construction loads—Those loads imposed on a partially completed or temporary structure during and as a result of the construction process. Construction loads include, but are not limited to, materials, personnel, and equipment imposed on the temporary or permanent structure during the construction process.

Drop-head shore—Shore with a head that can be lowered to remove forming components without removing the shore or changing its support for the floor system.

Fixed material loads (FML)—Loads from materials that are fixed in magnitude (e.g. weight of reinforced concrete).

Formwork engineer/contractor—Engineer of the formwork system or contractor in charge of designated aspects of formwork design and formwork operations.

Formwork or Formwork system—Total system of support for the freshly placed concrete, including form sheathing plus all supporting members, hardware, and bracing. The Formwork system may include all or some of the following subsystems:

Form—Temporary structure or mold for the support of concrete while it is setting and gaining sufficient strength to be self-supporting.

Falsework—A temporary structure erected to support work in the process of construction; composed of shoring or vertical posting and lateral bracing for forms for beams and slabs.

Shores—Vertical or inclined support members designed to carry the weight of forms, concrete, and construction loads.

Individual personnel load—A concentrated load that includes the weight of one person plus equipment carried by the person or equipment that can be readily picked up by a single person without assistance.

Materials Contained in Equipment—Materials being lifted by or contained in equipment are part of the equipment load, not a material load. Once such material has been discharged from the equipment, it becomes a material load.

Reshores—Shores placed snugly under a stripped concrete slab or other structural member after the original forms and shores have been removed from a full bay, requiring the new slab or structural member to deflect and support its own weight and construction loads applied before installation of the reshores.

Scaffolding—An elevated work platform used to support workmen materials and equipment, but not intended to support the structure being constructed.

Variable material loads (VML)—Loads from materials that vary in magnitude during the construction process (e.g. material storage).

Working surfaces—Floors, decks, or platforms of temporary or partially completed structures

which are or are expected to be subjected to construction loads during construction.

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CHAPTER 2—DESIGN OF FORMWORK

2.1—General

2.1.1 Scope: This chapter covers the requirements for the design of formwork.

2.1.2 Design responsibility

2.1.2.1 The contractor is responsible to design, fabricate, install, and remove formwork.

2.1.2.2 The designer of the structure shall show/include on the design documents:

(a) Location of composite members requiring shoring;
(b) Requirements for removal of shoring of composite members.

2.1.3 Design objectives

2.1.3.1 Formwork shall be designed so that it will safely support all vertical and lateral loads that might be applied until such loads can be supported by the concrete structure. Vertical and lateral loads shall be carried to the ground by the formwork system or by the in-place construction that has adequate strength for that purpose.

2.1.3.2 Formwork shall be designed and constructed so that concrete slabs, walls, and other members will have the correct dimensions, shape, alignment, elevation, and position within established tolerances.

2.1.3.3 Partially completed structures and temporary structures shall possess sufficient structural integrity, under all stages of construction, to remain stable and resist the loads specified herein. Stability of the incomplete structure and the possibility of progressive collapse shall be considered.

2.1.3.4 The effects of construction loads or conditions shall not adversely affect the serviceability or performance of the completed structure.

2.1.4 Use of manufactured systems and components

2.1.4.1 Manufactured systems and components shall comply with the requirements of Section 2.5.

2.1.5 Submittal of drawings and documents

2.1.5.1 When required by the contract documents, the formwork engineer/contractor shall submit detailed drawings, design calculations, or both, of proposed formwork for review and approval by the engineer/architect or approving agency before constructing forms.

2.1.5.2 The review, approval, or both, of the formwork drawings does not relieve the contractor of the responsibility for adequately constructing and maintaining the forms so that they will function properly.

2.1.5.3 Design values of construction live load, allowable vertical or lateral concrete pressure, and maximum equipment load, required soil bearing capacity, material specification, camber required, and other pertinent information, if applicable shall be shown on formwork drawings.

2.1.5.4 In addition to specifying types of materials, sizes, lengths, and connection details, formwork drawings shall provide for applicable details, such as:

(a) Procedures, sequence, and criteria for removal of forms, shores, reshores, and backshores and for retracting and resnugging drop-head shores to allow slab to deflect and support its own weight prior to casting of next level
(b) Design allowance for construction loads on new slabs when such allowance will affect the development of shoring schemes, reshoring schemes, or both (refer to 2.4 and 3.9 for shoring and reshoring of multistory structures)
(c) Anchors, form ties, shores, lateral bracing, and horizontal lacing
(d) Means to adjust forms for alignment and grade
(e) Waterstops, keyways, and inserts
(f) Working scaffolds and runways
(g) Weepholes or vibrator holes, where required
(h) Screeds and grade strips
(i) Location of external vibrator mountings
(j) Crush plates or wrecking plates where stripping can damage concrete
(k) Removal of spreaders or temporary blocking
(l) Cleanout holes and inspection openings

(m) Construction joints, contraction joints, expansion joints and isolation joints in accordance with contract documents
(n) Sequence of concrete placement and minimum elapsed time between adjacent placements
(o) Chamfer strips or grade strips for exposed corners and construction joints
(p) Reveals (rustications)
(q) Camber
(r) Mudsills or other foundation provisions for formwork
(s) Special form face requirements
(t) Notes to formwork erector showing size and location of conduits and pipes projecting through formwork
(u) Opening or block outs as specified in the contract documents.
(v) Temporary openings or attachments for climbing crane or other material handling equipment.

2.2—Basic design requirements

2.2.1 General

2.2.1.1 The design of formwork, shores, reshores and backshores shall be adequate to safely support loads transmitted to them.

2.2.1.2 Member design capacities shall be in accordance with Section 2.3.

2.2.2 Design loads

2.2.2.1 The design of formwork shall account for all construction loads, including vertical, horizontal, and impact as detailed in Chapter 3.

2.2.2.2 Design of formwork shall also consider the followings:

(a) Method of concrete placement;
(b) Rate of concrete placement;
(c) Avoidance of damage to previously constructed members;
(d) For post-tensioned members, allowance for movement of the member during application of the prestressing force without damage to the member.

2.2.3 Design analysis

2.2.3.1 The structural analysis of formwork system shall satisfy conditions of equilibrium and geometric compatibility.

2.2.3.2 The analysis shall consider and accommodate the effect of foundation settlement, interaction between elements of the falsework system and completed portions of the permanent structure, and load redistribution due to shrinkage and dead load deflection, as applicable.

2.2.3.3 For cast-in place prestressed construction, the falsework shall be designed to support any increased load resulting from load redistribution caused by the prestressing forces.

2.2.4 Deflection limits

2.2.4.1 The calculated vertical deflection for falsework members shall not exceed 1/240 of their span under the dead load of the concrete only, regardless of the fact that deflection may be compensated for by camber strips.

2.2.4.2 Formwork shall be designed and constructed so that vertical adjustments can be made to compensate for anticipated take-up, elastic deformations, and settlements.

2.2.5 Slenderness limits

2.2.5.1 For compression members, the slenderness ratio (ℓ/r), shall not exceed the following:

(a) Main load-carrying members
  (i) Steel-180
  (ii) Aluminum-100
(b) Bracing members
  (i) Steel-200
  (ii) Aluminum-150

2.2.5.2 The slenderness ratio (ℓ/r) of a tension member, other than guy lines, cables, and rods, shall not exceed 240 for a main member or 300 for a bracing member.

2.2.6 Bracing and lacing

2.2.6.1 The formwork system shall be designed to transfer all horizontal loads to the ground or to completed construction in such a manner as to ensure safety at all times.

2.2.6.2 Diagonal bracing shall be provided in vertical and horizontal planes where required to resist lateral loads and to prevent instability of individual members.

2.2.6.3 Horizontal lacing can be considered in design to hold in place and increase the buckling strength of individual shores and reshores or backshores.

2.2.6.4 Lacing shall be provided in whatever directions are necessary to produce the correct slenderness ratio (ℓ/r) for the load supported, where (ℓ) is the unsupported length and r is the least radius

of gyration. The braced system shall be anchored to ensure stability of the total system.

2.2.7 Overturning and Sliding

2.2.7.1 The falsework system, including individual elements and units of the system that are subject to overturning forces, shall be analyzed for stability against overturning and sliding with the falsework in the loaded and unloaded condition; that is, with and without the dead load of the concrete.

2.2.7.2 The ratio of the resisting moment to the overturning and sliding moment shall be equal to or greater than 1.5 for all load combinations. If the ratio of the resisting to the overturning moments is less than 1.5, external bracing shall be provided to resist the full overturning moment.

2.2.7.3 Except for bracing required to prevent overturning or collapse of the falsework system or any element of the system, the ability of falsework members to resist horizontal loads may include the contribution to stability provided by the supported structure.

2.2.7.4 The ratio of the total resisting force, caused by friction and adhesion, to the base shear, caused by lateral forces, shall be equal to or greater than 1.5 for all load combinations. If the ratio of the resisting force to sliding force is less than 1.5, external anchorage shall be provided to resist the full sliding force.

2.3—Design capacity of members

2.3.1 General

2.3.1.1 Member capacities for use in the design of formwork, exclusive of accessories, are determined in sections 2.3.2 through 2.3.4.

2.3.2 Steel members

2.3.2.1 Design of structural steel elements and systems of falsework shall be in accordance with Chapter 22 of SBC 201 and the relevant provisions of AISC 360.

2.3.2.2 Steel furnished for structural load-carrying purposes shall be properly identified for conformity to the ordered grade in accordance with the specified ASTM standard as per AISC 360 and AISI S100.

2.3.2.3 Steel that is not readily identifiable as to grade from marking and test records shall be tested to determine conformity to such standards.

2.3.2.4 For the design of cold-formed steel structural for falsework, members shall be designed according to the provisions in the AISI S100, except for cold-formed hollow structural sections (HSS), which are designed in accordance with AISC 360.

2.3.2.5 Alternatively, Structural Steel for falsework used in panel framing or bracing or heavy forms shall comply with the appropriate design standards such as AISC 325 or AISI D100.

2.3.3 Aluminum members

2.3.3.1 The quality, design, fabrication and erection of aluminum shall comply with AA ASM 35 and AA ADM 1.

2.3.4 Wood members

2.3.4.1 The design of structural elements or systems, constructed partially or wholly of wood or wood-based products, shall be in accordance with one of the methods cited in Chapter 23-Section :2301.2 of SBC 201.

2.3.4.2 All wood species with assigned allowable stresses in SASO standards shall be acceptable for use in falsework construction.

2.3.4.3 Used lumber of known species may be used in falsework construction under the following conditions:

(a) If the grade is known and the lumber is in good condition, the allowable stresses shall not exceed those for new lumber of the same grade,

(b) If the grade is unknown, it shall not be permitted, unless its grade is established by appropriate standard tests.

2.3.5 Foundations for formwork

2.3.5.1 Formwork footings and bracing anchors shall be designed to resist the loads imposed without exceeding the allowable soil bearing capacity, without incurring excessive settlements affecting the formwork structural integrity and stability, and without deviating from the specified concrete elevation.

2.3.5.2 If soil under mudsills is or may become incapable of supporting superimposed loads without appreciable settlement, it shall be stabilized or other means of support shall be provided. Mudsills shall be protected from loss of soil bearing strength. Causes might include scour due to running water, nearby excavations, or the increase of moisture content caused by the supporting soil becoming wet or saturated.

2.4—Design of shores

2.4.1 Loadings

2.4.1.1 Shores and reshores or backshores shall be designed to carry all loads transmitted to them. A rational analysis (ACI 347.2R and ACI SP-4) shall be used to determine the number of floors to be shored, reshored, or backshored; and to determine the loads transmitted to the floors, shores, and reshores or backshores as a result of the construction sequence.

2.4.2 Analysis

❖ In a common method of analysis, while reshoring remains in place at grade level, each level of reshores carries the weight of only the new slab plus other construction live loads. The weight of intermediate slabs is not included because each slab carries its own weight before reshores are put in place. Once the tier of reshores in contact with grade has been removed, the assumption is made that the system of slabs behaves elastically. The slabs interconnected by reshores will deflect equally during addition or removal of loads. Loads will be distributed among the slabs in proportion to their developed stiffness. The deflection of concrete slabs can be considered elastic, that is, neglecting shrinkage and creep. Caution shall be exercised when a compressible wood shoring system is used. Such systems tend to shift most of the imposed construction loads to the upper floors, which have less strength. Addition or removal of loads may be due to construction activity or to removing shores or reshores in the system. Shore loads are determined by equilibrium of forces at each floor level

2.4.2.1 The analysis shall consider, but shall not necessarily be limited to:

(a) Structural design load of the slab or member including live load, partition loads, and other loads for which the engineer of the permanent structure designed the slab.
(b) Dead load weight of the concrete and formwork.
(c) Construction live loads, such as the placing crews and equipment or stored materials.
(d) Specified design strength of concrete.
(e) Cycle time between the placement of successive floors.
(f) Strength of concrete at the time it is required to support shoring loads from above.
(g) The distribution of loads between floors, shores, and reshores or backshores at the time of placing concrete, stripping formwork, and removal of reshoring or backshoring.
(h) Span of slab or structural member between permanent supports.
(i) Type of formwork systems, that is, span of horizontal formwork components and individual shore loads.
(j) Minimum age of concrete when creep deflection is a concern.
(k) Loads applied due to post-tensioning transfer.

2.4.2.2 Shores in the lowest stories shall be designed to carry the full weight of concrete, formwork, and construction loads of all the floors above them prior to removal of the lowest story of shores supported on the ground or other unyielding support. Once the first floor of shores supported by the ground has been removed and replaced by reshores, the shores and reshores must be designed to carry all loads transmitted from the slabs above. Because the building slabs become part of the support system, the shoring/reshoring designer must consider their ability to support or transfer loads to and from the shores and reshores and to the building columns.

2.5—Manufactured systems and components

2.5.1 General

2.5.1.1 As used herein, manufactured components include the following classes of proprietary products:

2.5.1.2 Vertical shoring systems including tubular welded frame shoring, tube and coupler shoring, and components thereof.

2.5.1.3 Manufactured assemblies including single-post shores, brackets, jacks, joists, clamps, and similar devices manufactured for commercial use.

2.5.2 Maximum Loadings and Deflections

2.5.2.1 The maximum load to be used on any manufactured component, under any load sequence or combination, shall not exceed the manufacturer's recommendations.

2.5.2.2 A manufacturer's catalog, technical bulletin, or similar publication shall be furnished with the falsework drawings showing the use of manufactured components. The information furnished shall include, but not be limited to, test data and limitations and conditions governing the use of the component.

2.5.2.3 The dead load deflection of a manufactured component designed for use in a horizontal or inclined position shall not exceed 1/240 of the span length under the weight of the concrete only.

2.5.2.4 The use of a manufactured assembly for which no engineering data is furnished will not be permitted, unless the assembly has been tested under the formwork design.

2.5.2.5 The working load for such assemblies shall not exceed 40 percent of the maximum load sustained during the test.

2.5.3 Factor of Safety

2.5.3.1 The factor of safety for vertical shoring systems shall not be less than 2.5. This shall be clearly evident from a catalog or other engineering data furnished by the manufacturer.

2.5.3.2 The factor of safety for jacks that are not a part of a shoring system, and all types of manufactured assemblies, shall not be less than the minimum factor of safety required by the industry standard for the particular device, and in no case, shall the factor of safety be less than 2.0.

2.5.4 Members capacities

2.5.4.1 When fabricated form, shoring, or scaffolding units are used, manufacturer's recommendations for working capacities shall be followed if supported by engineering calculations or test reports of an approved testing agency. The effects of cumulative load duration shall be considered in accordance with the applicable design specification for the material.

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CHAPTER 3—CONSTRUCTION LOAD

3.1—Scope

3.1.1 This chapter covers the requirements for construction loads on formwork. It includes dead and live loads, lateral pressure of concrete, wind loads and seismic loads. It includes also shoring and floor loads in multi-story structures.

3.2—Load combinations

3.2.1 General: The formwork designer must determine the set of load combinations that cause the greatest resultant forces in the individual form components. Some judgment is required because all of the individual loads may not occur at the same time. Both allowable stress design (ASD) and load and resistance factor design (LRFD) combinations are listed.

3.2.2 ASD Combinations: The following ASD combinations cover most situations in formwork design.

$$
\begin{array}{|l|l|}
\hline
C_{DL} + C_{FML} + C_{VML} & A \\
C_{DL} + C_{FML} + C_{VML} + C_{PE} + C_H & B \\
C_{DL} + C_{FML} + C_{VML} + C_{PE} + 0.6\,W & C \\
C_{DL} + C_{FML} + C_{VML} + C_{PE} + 0.7E & D \\
0.6\,C_{DL} + (0.6\,W \text{ or } 0.7\,E) & E \\
C_{CP} & F \\
\hline
\end{array} \quad \textbf{(3-1)}
$$

where, C_{CP} = lateral pressure of fresh concrete; C_{DL} = construction dead load (self-weight of the form); C_{FML} = fixed material load (vertical dead load of placed concrete and reinforcement); C_H = horizontal construction loads; C_{PE} = personnel and equipment loads (live load during placing and finishing operations); C_{VML} = variable material load (concentrations of material placed on the form); E = earthquake or seismic load; and W = wind load.

❖ Lateral pressure of concrete is indicated as a separate load without combination in Eq. 3-1 (F) as it does not combine with the other loads in most cases. However, there are situations where lateral pressure can combine with other loads and these situations have to be recognized by the form designer when this occurs. The most unfavorable effects from both wind and earthquake loads shall be considered where appropriate, but they need not be considered simultaneously. Similarly, C_H need not be assumed to act simultaneously with wind or seismic loads.

3.2.3 LRFD Combinations: The following LRFD combinations cover most situations in formwork design.

$$
\begin{array}{|l|l|}
\hline
1.4\,C_{DL} + 1.2\,C_{FML} + 1.4\,C_{VML} & A \\
1.2\,C_{DL} + 1.2\,C_{FML} + 1.4\,C_{VML} + 1.6\,C_{PE} + 1.6\,C_H & B \\
1.2\,C_{DL} + 1.2\,C_{FML} + 1.4\,C_{VML} + 0.5\,C_{PE} + 1.0\,W & C \\
1.2\,C_{DL} + 1.2\,C_{FML} + 1.4\,C_{VML} + 1.6\,C_{PE} + 0.3\,W & D \\
1.2\,C_{DL} + 1.2\,C_{FML} + 1.4\,C_{VML} + 0.5\,C_{PE} + 1.0\,E & E \\
0.9\,C_{DL} + (1.0\,W \text{ or } 1.0\,E) & F \\
1.3\,C_{CP} \text{ (if full liquid head is assumed)} & G \\
1.6\,C_{CP} \text{ (otherwise)} & H \\
\hline
\end{array} \quad \textbf{(3-2)}
$$

❖ Lateral pressure can combine with other loads as discussed above in Section 3.2.2. Similarly, C_H need not be assumed to act simultaneously with wind or seismic loads.

3.3—Dead loads

3.3.1 Weight of reinforced concrete and form: The weight of reinforced concrete, C_{FML}, and the weight of the form, C_{DL}, are regarded as dead loads.

3.3.2 Unit material weights: Table 3-1 provides information for unit material weights for calculating the dead loads.

3.4—Live loads

3.4.1 General

3.4.1.1 Material storage, C_{VML}, and workers and their equipment, C_{PE}, runways, and impact imposed during processes of construction are regarded as live loads.

3.4.2 Personnel and Equipment Loads, C_{PE}

3.4.2.1 Concentrated Loads: The personnel and equipment concentrated loads shall be the maximum loads expected in the construction process, but shall be no less than those given in Table 3-2. The concentrated load shall be located to produce the maximum strength and/or serviceability conditions in the structural members. The designer of the formwork shall consider each

category of minimum concentrated personnel and equipment load that is likely to occur during the construction process.

3.4.2.2 Uniformly Distributed Loads: The construction live load shall consist of the actual weight of any equipment to be supported applied as concentrated loads at the points of contact, plus a uniform load as the vertical load from the combination of personnel, equipment, and material in transit or staging. The designer of the formwork is permitted to design for the tabulated uniform loads in Table 3-3.

3.4.2.3 Outside edge of deck overhangs Load: For the design of the deck overhangs a linear load of 1.1 kN/m shall be applied on the outside edge plus the actual weight of any equipment to be supported applied as concentrated loads at the points of contact plus the uniform load given in Table 3-3.

3.4.2.4 Starting and Stopping Equipment Loads: When impact from starting and stopping of unusually heavy equipment or dumping of concrete can be anticipated, an analysis of the lateral forces generated shall be made. If it is desired to investigate the effects of starting and stopping of a heavy equipment having mass (m) on the deck, the horizontal construction loads, C_H equal the forces F developed which can be estimated using the expression:

$$F = ma \qquad \textbf{(3-3)}$$

where, a = average acceleration or deceleration of equipment, m/s^2; F = average force, N; and m = mass of loaded equipment, kg.

3.4.3 Impact Loads

3.4.3.1 The concentrated loads in Table 3-2 include adequate allowance for ordinary impact conditions.

3.4.4 Pattern Loading

3.4.4.1 The formwork designer shall consider patterns of construction loads when such loadings produce more demanding effects than does application of the full intensity of the construction load over the entire structure.

3.4.4.2 When unusual unbalanced loading from unsymmetrical placement of concrete is anticipated, an analysis of the lateral forces generated shall be made.

3.4.5 Special Loading Conditions

3.4.5.1 The formwork shall be designed for any special conditions of construction likely to occur, such as unsymmetrical placement of concrete, impact of machine-delivered concrete, uplift from concrete pressure, uplift from wind, concentrated loads of reinforcement, form handling loads, and storage of construction materials.

3.4.5.2 Form designers shall provide for special loading conditions, such as walls constructed over spans of slabs or beams that exert a different loading pattern before hardening of concrete than that for which the supporting structure is designed.

3.4.5.3 Imposition of any construction loads on the partially completed structure shall not be allowed, except as specified in formwork drawings or with the approval of the engineer/ architect.

3.4.6 Post-tensioning loads

3.4.6.1 Shores, reshores, and backshores shall be analyzed for both concrete placement loads and for all load transfer that takes place during post-tensioning.

3.5—Lateral pressure of concrete, C_{CP}

3.5.1 Distribution of lateral pressure of concrete

3.5.1.1 The lateral pressure of concrete, C_{CP} (kPa), shall be determined in accordance with Eq. (3-4). The set characteristics of a mixture shall be understood, and using the rate of placement, the level of fluid concrete can be determined. For columns or other forms that can be filled rapidly before concrete stiffening, (h) shall be taken as the full height of concrete in the form or the distance between horizontal construction joints when more than one placement of concrete is to be made. (h) shall not be more than 3m.

$$C_{CP} = \rho\, g\, h \qquad \textbf{(3-4)}$$

where, C_{Cp}= concrete lateral pressure, kPa; g = gravitational constant, 9.81×10^{-3} kN/kg; h = depth of fluid or plastic concrete from top of placement to point of consideration, m; and ρ = density of concrete kg/m^3

3.5.2 Pumping from the base of the form

3.5.2.1 If concrete is pumped from the base of the form, the form shall be designed for full hydrostatic head of concrete, $C_{CP} = \rho\, g\, h$, plus a minimum allowance of 25% for pump surge pressure.

3.5.3 Special conditions

3.5.3.1 Additional allowance for pressure shall be considered when using external vibration or concrete made with shrinkage-compensating or expansive cements. Pressures in excess of the equivalent hydrostatic head can occur.

3.6—Wind loads

3.6.1 Ultimate Wind Speed

3.6.1.1 The Ultimate wind speed, *V*, used in the determination of design wind loads shall be determined from (SBC 301, Chapter 26). When projects are located in the Special Wind Regions, the specific provisions of SBC 301 shall be consulted.

3.6.2 Design Wind Speed

3.6.2.1 The construction period design wind speed, V_C, is calculated by multiplying the ultimate wind speed, *V*, by the appropriate Construction Period Factor from Table 3-4 in accordance to Eq. (3-5).

$$V_C = C_{PF} \times V \qquad \textbf{(3-5)}$$

3.6.3 Design Velocity Pressure

3.6.3.1 Using the construction period design wind speed, the design velocity pressure q_z in N/m^2 is determined by using Eq.(3-6)

$$q_z = 0.613\, K_z\, K_{zt}\, K_d\, (V_C)^2 \qquad \textbf{(3-6)}$$

where, K_d = 0.85; K_z = velocity pressure exposure coefficient, refer to Section 27.3.1 in SBC 301; K_{zt} = topographic factor from SBC 301-Section 26.8.2, most typically 1.0 except when the formwork is located on a hill top or escarpment; and V_C = construction period design wind speed, m/s.

3.6.4 Design Wind Load

3.6.4.1 The wind load on formwork systems, F_w, can be determined using Eq. (3-7)

$$F_w = q_z G C_f A_f \quad \text{(N)} \qquad \textbf{(3-7)}$$

where, q_z = design velocity pressure evaluated at height z; G = gust effect factor (0.85 for formwork); C_f =Net force coefficient, refer to Table 3-5; and A_f= projected face area of all formwork members in the plane exposed to the wind direction, m^2.

3.6.4.2 Table 3-5 provides C_f values for column and wall forms of different dimensions.

3.6.4.3 Wind load shall be determined in a minimum of two perpendicular directions, one of which being the exposed face with the greatest projected area. For each direction of wind loading, formwork shall be designed to resist the full force of wind load calculated along that direction as well as 50% of the wind load calculated for the perpendicular direction acting simultaneously.

3.6.5 Wind Load on Wall and Column Forms

3.6.5.1 For freestanding wall form exposed to wind, the entire length of formwork shall be designed for the highest pressure. The pressure magnitude will vary depending on the length of the wall form (*B*) versus the height (*h*) or (*B*/*h*).

3.6.5.2 The net force coefficients values given in Table 3-5 are higher for larger *B*/*h*; thus, the designer of formwork shall consider using the highest (*B*/*h*) expected in the use of a particular form.

3.6.5.3 Column forms of typical heights can be considered as very short walls of height (*h*) and width (*B*) where wind eccentricity is minimal.

3.6.5.4 The wind force calculated is applied to the wall form slightly above mid-height (0.55h) because the wind pressure is somewhat higher near the top of the wall than the bottom.

3.7—Seismic loads

3.7.1 Seismic loads need not be considered unless required by the authority having jurisdiction.

3.8—Minimum loads

3.8.1 Minimum Dead Load

3.8.1.1 Loads to be assumed in design are as follows:

(a) The greater of the weight of concrete being supported, or 2.5 kN/m^2 on the horizontal projected area of the form.

(b) The greater of the weight of the form supported by the falsework or 0.5 kN/m^2 on the horizontal projected area.

3.8.2 Minimum Live Load

3.8.2.1 Vertical supports and horizontal framing components of formwork shall be designed for a minimum live load as follows:

(a) 2.5 kN/m^2 of horizontal projection to account for workers, runways, screeds, and other equipment.

(b) When motorized carts are used, the minimum load shall be 3.6 kN/m^2 (see Table 3-3).

3.8.3 Minimum Dead Loads and Live Loads

3.8.3.1 Regardless of slab thickness, the minimum design value for combined placed concrete dead load and personnel and equipment live load shall be:

(a) For ASD, 5 kN/m^2, or 6 kN/m^2 if motorized carts are used.
(b) For LRFD, the minimum factored dead plus live load from Eq.(3-2) shall be 7 kN/m^2, or 9 kN/m^{2}if motorized carts are used.

3.8.4 Minimum Horizontal Loads

3.8.4.1 General: Braces and shores shall be designed to resist all horizontal loads such as wind, cable tensions, inclined supports, dumping of concrete, and starting and stopping of equipment. Wind loads on enclosures or other wind breaks attached to the formwork shall be considered in addition to these loads.

3.8.4.2 Minimum wind Pressure: Formwork exposed to the elements shall be designed for wind pressures determined in accordance with SBC 301 with minimum lateral wind pressure shall not be less than 0.75 kPa. Consideration shall be given to possible wind uplift on the formwork.

3.8.4.3 Minimum horizontal load on elevated floor formwork: For elevated floor formwork, the applied value of horizontal load due to wind, dumping of concrete, inclined placement of concrete, and equipment acting in any direction at each floor line shall produce effects not less than the effect of 1.5 kN/m of floor edge OR 2% of total dead load on the form distributed as a uniform load per linear meter of slab edge, whichever is greater.

3.8.4.4 Minimum horizontal load on wall and column formwork: For wall and column formwork bracing design, the applied value of horizontal load due to wind and eccentric vertical loads shall produce effects not less than the effect of 1.5 kN/m of wall length or column width, applied at the top.

3.9—Shoring and floor loads in multi-story structures

3.9.1 General

3.9.1.1 Before construction, an overall plan for scheduling of shoring and reshoring or backshoring, and calculation of loads transferred to the structure, shall be prepared by a qualified and experienced formwork designer.

3.9.1.2 The structure's capacity to carry formwork shoring and reshoring loads shall be reviewed and approved by the engineer/architect. The plan for shoring and its execution remain the responsibility of the contractor.

3.9.1.3 Contract documents or the authority having jurisdiction may require the contractors to supply to the building official, upon request, the structural analysis and concrete strength requirements used in planning and implementing shoring/reshoring operations. Such data and information shall be furnished to the engineer/architect who shall evaluate the effects of construction loads on the immediate and long-term deflections.

3.9.1.4 Where shores are required to support the load of newly placed concrete, these shores shall be maintained until the concrete has gained enough strength to support applicable dead and construction loads. Where shoring is continuous over several floors, the calculated loads on these shores shall be cumulative unless and until the shores have been released and reset to allow the slab in question to carry its own dead and construction loads. Such release shall not occur until the concrete is capable of carrying its own dead load.

3.9.1.5 Shoring and reshoring shall be provided for an adequate number of floor levels to distribute the construction loads in such a way that the imposed loads are within the strength capacities of the floors below without causing excessive stress, deflections, or cracking.

3.9.1.6 Each structure and job-specific circumstances shall be individually evaluated. Depending on the specifics of the structural capacity and the planned construction sequence, more or possibly less levels of reshoring may be required.

3.9.2 Post-tensioning effects on shoring and reshoring

3.9.2.1 The formwork engineer/ contractor shall plan the shoring and reshoring for post-tensioned structures in close coordination with the engineer/architect. Information needed for development of safe shoring and reshoring operations includes:

(a) Members to be post-tensioned;
(b) Design live loads and dead loads; and
(c) Post-tensioning sequence and the magnitude of stressing at each stressing stage.

3.9.2.2 The construction load distribution is calculated corresponding to two construction stages. The first stage is during concrete placement of the top active level, and the second stage during post-tensioning.

3.9.2.3 The use of ACI simplified methods to evaluate construction load distribution between concrete slabs and the shoring/reshoring system shall be allowed.

❖ **Typical construction phases**

In a typical construction cycle for a multistory cast-in-place concrete building where both shores and reshores are used, there are four construction phases:

a) Phase 1—Installation of the shores and form followed by casting of the floor slab

b) Phase 2—Removal of the shores and form from a full bay, allowing the slab to deflect and carry its own weight and any applied construction loads

c) Phase 3—Removal of reshores at the lowest interconnected level

d) Phase 4—Placement of reshores in the story from which the shores and forms were removed; reshores are placed snugly without initially carrying any load.

The construction load redistribution depends on the sequence and magnitude of tensioning at each stage of stressing. When a slab is post-tensioned, a portion of the shore load is transferred to the supporting beams. If the beam is shored, the beam shoring has to have the ability to carry this redistributed load. When the beams are post-tensioned, a portion of the shore load is transferred to the supporting columns or girders. The load transfer associated with posttensioning of the beams can cause significant increases in the shoring loads at the beam/girder intersections for the period of time in which the girders have not yet been stressed. The maximum construction loading condition for shoring occurs when slabs are fully stressed first, followed by beams, then girders. In this case, a careful analysis of the load transfer to the beam and girder shores/reshores is needed. Shall the tensioning sequence be reversed or the magnitude of stressing at each stage be reduced, the construction load redistribution during tensioning will be different and, most likely, will result in lower shore loads.

The design of shoring/reshoring for post-tensioned construction requires the engineer to understand many variables such as site conditions, shoring system type, and numerous combinations of stressing sequences and the magnitude of stressing. Therefore, only general guidelines are presented in this Code. Given the variability of design and construction methods, the construction of each project shall be planned carefully in advance by the formwork engineer/contractor in close coordination with the engineer/ architect. Information shall be exchanged regarding design details and construction methods. A clear understanding shall be established for each party's responsibility in determining post-tensioning procedures and shoring/reshoring operations.

Construction load distribution (Simplified method):

The analysis method, now known as the simplified method, is based on a single-bay structure model with the following assumptions:

a) Ground-level or other grade base support is rigid

b) All previously cast slabs are identical and have equal stiffness

c) Shores and reshores are spaced closely enough to treat their reactions as a distributed load

d) Shores and reshores are infinitely stiff relative to the slabs

e) Reshores are installed snug-tight without initially carrying any load.

If special situations are encountered (e.g. the first few floors sometimes have a different structural design to accommodate higher service loads) an additional analytical consideration shall be required.

If some lower floors are stiffer than subsequent floors, the stiffer floors will carry more load from operations above. Variations in each slab's self-weight will also require consideration.

Application of the simplified method

Table C3-1 demonstrates the application of the simplified method. The example uses one level of shores and two levels of reshores. The construction live loads and weight of forms and shores are included in the load analysis. The slabs are assumed to have equal thickness and stiffness and, therefore, the construction loads are distributed equally among the slabs. The shores and reshores are assumed to be infinitely stiff relative to the supported slabs. Table C3-1 shows a sample load case with formwork system loads and construction loads as a proportion of slab self-weight. Actual construction live loads and formwork loads vary from project to project.

Following the four phases of construction, each floor level is subjected to construction loads that vary in magnitude as construction advances.

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Table 3-1: Unit material weight

Material	Unit Weight (kN/m^3)
Aluminum Alloy	27.0
Plain Concrete	23.5
Prestressed Concrete	24.5
Reinforced Concrete	24.0
Granular Soil/ Crushed Stones	22.0
Steel	77.0
Hardwood	9.5
Softwood	6.0
Water	9.8

Table 3-2: Minimum Concentrated Personnel and Equipment Loads

Action	Minimum Load[a] [kN]	Area of Load Application [mm × mm]
[b]Each person	1.1	300 × 300
Wheel of manually powered vehicle	2.2	Load divided by tire pressure[c]
Wheel of powered equipment	8.9	Load divided by tire pressure[c]

[a] Use actual loads where they are larger than tabulated here.
[b] The spacings of the 1.1 kN concentrated loads need not be less than 460 mm c. to c.
[c] For hard rubber tires, distribute load over an area 25 mm × the width of the tire.

Table 3-3: Classes of Working Surfaces for Combined Uniformly Distributed Loads

Operational Class[b, c]	Uniform Load[a] (kN/ m^2)
Light Duty: sparsely populated with personnel, hand-operated equipment, staging of materials for lightweight construction	1.2
Medium Duty: concentrations of personnel, staging of materials for average construction	2.4
Heavy Duty: material placement by motorized buggies, staging of materials for heavy construction	3.6

[a] Loads do not include construction dead load, C_{DL}, or fixed material loads, C_{FML}.
[b] OSHA categories.
[c] Where the construction operation does not fit the definitions in this Table, the design shall be for the actual loads. Concentrated loads shall be considered separately.

Table 3-4: Construction Period Factor C_{PF}

Construction Period	C_{PF}
Less than 6 weeks	0.75
6 weeks to 1 year	0.80
1 to 2 years	0.85
2 to 5 years	0.90

Table 3-5: Force coefficients for wall and column forms

Element	Aspect ratio *B/h*	Force Coefficient C_f
Column forms	0.1	1.70
	0.2	1.65
	0.5	1.55
Wall forms	≤ 2	1.8
	3	2.08
	4	2.32
	5	2.48
	6	2.64
	7	2.72
	8	2.84
	9	2.92
	10	3.00
	13	3.20
	≥ 45	3.44

Table C3-1: Simplified analysis of loads on shores and slabs using one level of shoring, two levels of reshoring

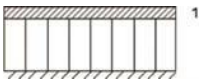
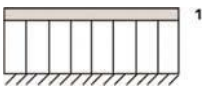
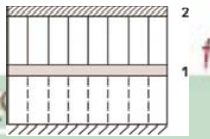
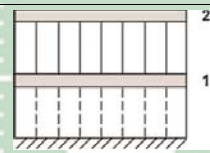
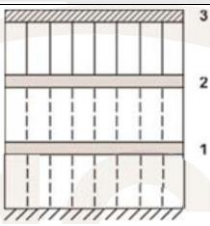
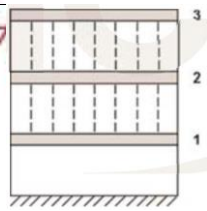
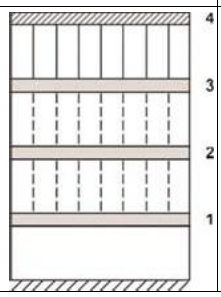
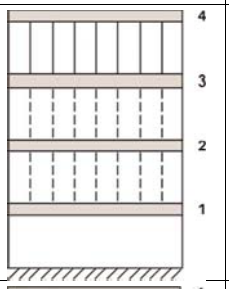
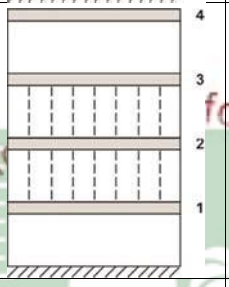
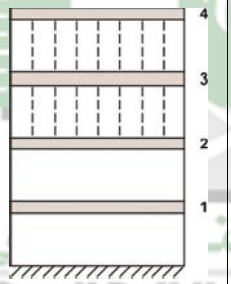
Step	Operation and remarks	Structure status	Load on slab in multiples of *D*			Shore/reshore load at end of operation
			At beginning	Change during operation	Total at end of operation	
1	Place Level 1 concrete. Full load is transmitted to ground by shores.		0	0	0	1.5 D
2	Construction live load is gone. Remove Level 1 shores, allowing Slab 1 to carry its own weight. Then place reshores beneath it, snug but not loaded.		0	+1D	1D	0
3	Form, shore, and place Level 2 concrete. Slab 1 cannot deflect and all added load goes through reshores to ground.		0 1D	0 0	0 1D	1.5*D* 1.5*D*
4	Slab 2 achieves required strength and construction live load is gone. Remove the Level 2 forms and shores, allowing Slab 2 to carry its own weight. Then place reshores beneath it, snug but not loaded.		0 1*D*	+1*D* 0	1D 1D	0 0
5	Form, shores, and place Level 3 concrete, including the 0.5D construction live load and shore load. All added load goes through shores to the ground because slabs cannot deflect further.		0 1D 1D	0 0 0	0 1D 1D	1.5*D* 1.5*D* 1.5*D*
6	Construction live load is assumed removed as Slab 3 achieves required strength. Remove shores beneath Level 3, allowing it to carry its own weight. This leaves no net load in reshores beneath Level 1, and they are removed and installed snugly beneath Level 3. They carry no heat.		0 1D 1D	+1D 0 0	1D 1D 1D	0 0 —
7	Form, shore, and place Level 4 concrete with the assumed 0.5D construction live load and shore load. The total new applied load, 1.5D, is distributed equally to the three interconnected slabs.		0 1*D* 1*D* 1D	0 +0.5*D* +0.5*D* +0.5*D*	0 1.5*D* 1.5*D* 1.5*D*	1.5*D* 1*D* 0.5*D* —

Table C3-1 (Contd.)

Step	Operation and remarks	Structure status	Load on slab in multiples of *D*			Shore/reshore load at end of operation
			At beginning	Change during operation	Total at end of operation	
8	Level 4 concrete achieves required strength and the construction live load of 0.4D is removed in equal parts from the slabs to which it was distributed.		0 1.5*D* 1.5*D* 1.5*D*	0 -0.13*D* -0.13*D* -0.13*D*	0 1.37*D* 1.37*D* 1.37*D*	1.1*D* 0.73*D* 0.36*D*
9	Remove shores beneath Level 4, causing that slab to carry its own weight. The load in those shores, including their weight, is removed from the slabs to which it had been distributed.		0 1.37*D* 1.37*D* 1.37*D*	0 -0.37*D* -0.37*D* -0.37*D*	1D 1D 1D 1*D*	— 0 0
10	Move reshores beneath Level 2 up, placing them snugly beneath Level 4, where they carry no load. There is no change in system loads. System conditions are now the same as at the end of Step 6, and when the Level 5 slab is placed, the cycle repeats.		1D 1D 1D 1D	0 0 0 0	1D 1D 1D 1D	0 0 —

Notes:

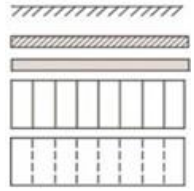
The results indicated in the table shall not be used for actual projects because the actual construction live loads and formwork loads may differ from those assumed in the table.

D is weight of slab.

Assumed construction live load = 0.4*D*

Assumed shore and form weight = 0.1*D*

Reshore weight is neglected.

	= rigid support at starting level
	= freshly placed slab
	= hardened slab
	= story of shores and formwork
	= story of reshores

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CHAPTER 4—CONSTRUCTION CONSIDERATIONS

4.1—General

4.1.1 Formwork engineers and formwork contractors shall follow all regulations pertaining to forming and shoring to maintain safe conditions for workers and the public.

4.2—Construction practices and workmanship

4.2.1 Fabrication and assembly details of formwork shall consider Sections 4.2.1.1 through 4.2.1.7 .

4.2.1.1 Studs, wales, or shores shall be properly spliced.

4.2.1.2 Joints or splices in sheathing, plywood panels, and bracing shall be staggered.

4.2.1.3 Shores shall be installed plumb and with adequate bearing and bracing.

4.2.1.4 Use specified size and capacity of form ties or clamps.

4.2.1.5 All form ties or clamps shall be installed and properly tighten as specified. All threads shall fully engage the nut or coupling. A double nut may be required to develop the full capacity of the tie.

4.2.1.6 Forms shall be sufficiently tight to prevent loss of mortar from the concrete.

4.2.1.7 Access holes may be necessary in wall forms or other high, narrow forms to facilitate concrete placement.

4.2.2 For Joints in the concrete, the following shall be considered:

4.2.2.1 Contraction joints, expansion joints, control joints, construction joints, and isolation joints shall be installed as specified in the contract documents or as requested by the contractor and approved by the engineer/architect.

4.2.2.2 Bulkheads for joints shall preferably be made by splitting along the lines of reinforcement passing through the bulkhead so that each portion can be positioned and removed separately without applying undue pressure on the reinforcing rods, which could cause spalling or cracking of the concrete. When required on the engineer/architect's plans, beveled inserts at control joints shall be left undisturbed when forms are stripped, and removed only after the concrete has been sufficiently cured. Wood strips inserted for architectural treatment shall be kerfed to permit swelling without causing pressure on the concrete.

4.2.3 Sloped surfaces steeper than 1.5 horizontal to 1 vertical shall be provided with a top form to hold the shape of the concrete during placement, unless it can be demonstrated that the top forms can be omitted.

4.2.4 Cleanup and coatings of forms shall be conducted as follows:

4.2.4.1 Forms shall be thoroughly cleaned of all dirt, mortar, and foreign matter and coated with a release agent before each use. Where the bottom of the form is inaccessible from within, access panels shall be provided to permit thorough removal of extraneous material before placing concrete.

4.2.4.2 Form coatings shall be applied before placing of reinforcing steel and it shall not be used in such quantities as to run onto bars or concrete construction joints.

4.2.5 Construction operations on the formwork during casting shall consider the following:

4.2.5.1 Building materials, including concrete, shall not be dropped or piled on the forms in such a manner as to damage or overload it.

4.2.5.2 Runways for moving equipment shall be provided with struts or legs as required and shall be supported directly on the forms or structural member. They shall not bear on nor be supported by the reinforcing steel unless special bar supports are provided. The forms shall be suitable for the support of such runways without significant deflections, vibrations, or lateral movements.

4.2.6 When loading new slabs the following shall be considered:

4.2.6.1 Guard against overloading of new slabs by temporary material stockpiling or by early application of permanent loads.

4.2.6.2 Loads, such as aggregate, lumber, reinforcing steel, masonry, or machinery shall not

be placed on new construction in such a manner as to damage or overload it.

4.3—Tolerances in formwork construction

4.3.1 Tolerances shall be specified by the engineer/ architect so that the contractor will know precisely what is required and can design and maintain the formwork accordingly

4.3.2 Formwork shall be constructed with such dimensions so the resulting concrete members are within the specified dimensional tolerances of SBC 304.

4.3.3 The engineer/architect shall specify tolerances or require performance appropriate to the type of construction.

4.3.4 The contractor shall set and maintain concrete forms, including any specified camber, to ensure completed work is within the tolerance limits.

4.4—Irregularities in formed surfaces

4.4.1 The engineer/architect shall indicate which class of formed surface is required for the work being specified with reference to Table 4-1, considering Sections 4.4.1.1 through 4.4.1.4 :

4.4.1.1 Class A is suggested for surfaces prominently exposed to public view where appearance is of special importance.

4.4.1.2 Class B is intended for coarse-textured, concrete-formed surfaces intended to receive plaster, stucco, or wainscoting.

4.4.1.3 Class C is a general standard for permanently exposed surfaces where other finishes are not specified.

4.4.1.4 Class D is a minimum-quality requirement for surfaces where roughness is not objectionable, usually applied where surfaces will be permanently concealed.

4.4.2 If surface appearance is important, forms shall not be reused if damage from previous use would cause impairment to concrete surfaces.

4.5—Shoring and Centering

4.5.1 Shoring

4.5.1.1 Shoring shall be supported on satisfactory foundations, such as spread footings, mudsills, slabs-on-ground, piers, caissons, or piling.

4.5.1.2 Shoring location on intermediate slabs or other construction already in place shall be approved by the engineer/architect.

4.5.1.3 If reshores do not align with the shores above, then reversal of bending moments shall be calculated and taken into consideration.

4.5.1.4 Reshores shall be prevented from falling by such means as spring clips at the top of reshores and positively attaching perimeter reshores back into the interior of the structure with appropriate lacing or bracing.

4.5.1.5 The reshoring plan shall be submitted to the engineer/architect for review related to effects on permanent structures.

4.5.1.6 Multi-tier shoring: Single post shoring in two or more tiers is a dangerous practice and shall be avoided.

4.5.1.7 Special attention shall be given to beam and slab construction or one- and two-way joist construction to prevent local overloading when a heavily loaded shore rests on a thin slab.

4.5.1.8 Vertical shores shall be erected so that they cannot tilt and shall have a firm bearing. Inclined shores shall be braced securely against slipping, sliding, or buckling. Moreover, Connections of shore heads to other framing shall be adequate to prevent the shores from falling out when reversed bending causes upward deflection of the forms

4.5.2 When centering is used, lowering is generally accomplished by the use of sand jacks, jacks, or wedges beneath the supporting members.

4.6—Removal of Forms and Shores

4.6.1 Compliance requirements:

4.6.1.1 Before starting construction, the contractor shall develop a procedure and schedule for removal of formwork and installation of reshores, and shall calculate the loads transferred to the structure during this process.

4.6.1.2 Structural analysis and concrete strength requirements used in planning and implementing the formwork removal and reshore installation shall be furnished by the contractor to the licensed design professional and to the building official, when requested.

4.6.1.3 No construction loads shall be placed on, nor any formwork removed from, any part of the structure under construction except when that portion of the structure in combination with remaining formwork has sufficient strength to

support safely its weight and loads placed thereon and without impairing serviceability.

4.6.1.4 Sufficient strength shall be demonstrated by structural analysis considering anticipated loads, strength of formwork, and an estimate of in-place concrete strength.

4.6.1.5 The estimate of in-place concrete strength shall be based on tests of field-cured cylinders or on other procedures to evaluate concrete strength approved by the licensed design professional and, when requested, approved by the building official.

4.6.1.6 Formwork shall be removed in such a manner not to impair safety and serviceability of the structure.

4.6.1.7 Concrete exposed by formwork removal shall have sufficient strength not to be damaged by the removal.

4.6.1.8 Formwork supports for post-tensioned members shall not be removed until sufficient post-tensioning has been applied to enable post-tensioned members to support their dead load and anticipated construction loads.

4.6.1.9 No construction loads exceeding the combination of superimposed dead load plus live load shall be placed on any unshored portion of the structure under construction, unless analysis indicates adequate strength to support such additional loads and without impairing serviceability.

4.6.2 Removal of formwork:

4.6.2.1 In determining the time for removal of formwork, consideration shall be given to the construction loads, in-place strength of concrete, and possibility of deflections greater than acceptable to the licensed design professional. Construction loads may be greater than the specified live loads. Even though a structure may have adequate strength to support the applied loads at early ages, deflections can cause serviceability problems.

4.6.2.2 The removal of formwork for multistory construction shall be a part of a planned procedure developed by the contractor that considers the temporary support of the entire structure as well as each individual member. Such a procedure shall be planned before construction and shall be based on a structural analysis taking into account at least (a) through (e):

(a) The structural system that exists at the various stages of construction, and the construction loads corresponding to those stages;
(b) The in-place strength of the concrete at the various stages during construction;
(c) The influence of deformations of the structure and shoring system on the distribution of dead loads and construction loads during the various stages of construction;
(d) The strength and spacing of shores or shoring systems used, as well as the method of shoring, bracing, shore removal, and reshoring including the minimum time interval between the various operations;
(e) Any other loading or condition that affects the safety or serviceability of the structure during construction.

4.6.2.3 The formwork engineer/contractor shall communicate specific sequences of erection and removal of shoring and reshoring on the formwork drawings.

4.6.2.4 Because the minimum stripping time is usually a function of concrete strength, the preferred method of determining stripping time is a comparison of the actual strength gained to the strength required for stripping the element. The elapsed times shown in Table 4-2 may be used as guidance for determining stripping time for general planning purposes. The times shown represent a cumulative number of days, or hours, not necessarily consecutive, during which the temperature of the air surrounding the concrete is above 10°C.

TABLES OF Chapter 4

Table 4-1: Permitted abrupt or gradual irregularities in formed surfaces as measured within a Shoring and Centering

Class of Concrete			
A	**B**	**C**	**D**
3 mm	6 mm	13 mm	25 mm

Table 4-2: Guidance for stripping time when contract documents do not specify stripping time of stripping strength required

Structural element supported	Elapsed time
Walls[a]	12 hours
Columns[a]	12 hours
Sides of beams and girder[a]	12 hours
Pan joist forms[b]	
760 mm wide or less	3 days
Over 760 mm wide	4 days
Arch centers	14 days
Joist, beam or girders soffits	
Under 3 m clear span between structural supports	7 days[c]
3 to 6 m clear span between structural supports	14 days[c]
Over 6 m clear span between structural supports	21 days[c]
One-way floor slabs	
Under 3 m clear span between structural supports	4 days[c]
3 to 6 m clear span between structural supports	7 days[c]
Over 6 m clear span between structural supports	10 days[c]
Two-way slab systems[d]	Removal times are contingent on placement of reshores where required. Reshores shall be placed as soon as practicable after atripping operations are complete but not later than the end of the working day in which stripping occurs. Where reshores are required to implement early stripping while minimizing sag or creep (rather than for distribution of superimposed construction loads as covered in section 3.9), capacity and spacing of such reshores shall be designed by the formwork engineer/contractor and approved by the engineer/architect.
Post tensioned slab system[d]	As soon as post-tensioned operations have been completed and approved

[a] Where such forms also support formwork for slab or beam soffits, the removal times of the latter shall govern.
[b] Of the type than can be removed without disturbing forming or shoring.
[c] Where forms can be removed without disturbing shores, use half of values shown but bot less than 3 days.
[d] Refer to section 3.9 for special conditions affecting the number of floors to remain shored or reshored.

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CHAPTER 5—SAFETY AND INSPECTION OF FORMWORK

5.1—General

5.1.1 No construction loads shall be placed on a concrete structure or portion of a concrete structure unless the employer determines, based on information received from a person who is qualified in structural design, that the structure or portion of the structure is capable of supporting the loads.

5.1.2 All protruding reinforcing steel, onto which employees could fall, shall be guarded to eliminate the hazard of impalement.

5.1.3 For post-tensioning operations, the following requirements shall be met:

5.1.3.1 No employee (except those essential to the post-tensioning operations) shall be permitted to be behind the jack during tensioning operations.

5.1.3.2 Signs and barriers shall be erected to limit employee access to post-tensioning area during tensioning operations.

5.1.4 No employee shall be permitted to ride concrete buckets.

5.1.5 When working under loads, the following requirements shall be met:

5.1.5.1 No employee shall be permitted to work under concrete buckets while buckets are being elevated or lowered into position.

5.1.5.2 To the extent practical, elevated concrete buckets shall be routed so that no employee, or the fewest number of employees, are exposed to the hazards associated with falling concrete buckets.

5.1.6 No employee shall be permitted to apply a cement, sand, and water mixture through a pneumatic hose unless the employee is wearing protective head and face equipment.

5.2—Requirements for equipment and tools

5.2.1 Bulk storage bins, containers, and silos shall be equipped with the following:

(a) Conical or tapered bottoms; and
(b) Mechanical or pneumatic means of starting the flow of material

5.2.1.1 No employee shall be permitted to enter storage facilities unless the ejection system has been shut down, locked out, and tagged to indicate that the ejection system is not to be operated.

5.2.1.2 Concrete mixers with 0.8 m^3 or larger loading skips shall be equipped with the following:

(a) A mechanical device to clear the skip of materials; and
(b) Guardrails installed on each side of the skip.

5.2.1.3 Powered and rotating type concrete troweling machines that are manually guided shall be equipped with a control switch that will automatically shut off the power whenever the hands of the operator are removed from the equipment handles.

5.2.1.4 Concrete buggy handles shall not extend beyond the wheels on either side of the buggy.

5.2.1.5 Concrete pumping systems:

(a) Concrete pumping systems using discharge pipes shall be provided with pipe supports designed for 100 percent overload.
(b) Compressed air hoses used on concrete pumping system shall be provided with positive fail-safe joint connectors to prevent separation of sections when pressurized.

5.2.1.6 Concrete buckets:

(a) Concrete buckets equipped with hydraulic pneumatic gates shall have positive safety latches or similar safety devices installed to prevent premature or accidental dumping.
(b) Concrete buckets shall be designed to prevent concrete from hanging up on top and the sides.

5.2.2 Sections of tremies and similar concrete conveyances shall be secured with wire rope (or equivalent materials) in addition to the regular couplings or connections.

5.2.3 Bull float handles, used where they might contact energized electrical conductors, shall be constructed of nonconductive material or insulated with a nonconductive sheath whose electrical and mechanical characteristics provide the equivalent protection of a handle constructed of nonconductive material.

5.2.4 Masonry saws:

5.2.4.1 Masonry saws shall be guarded with a semicircular enclosure over the blade.

5.2.4.2 A method for retaining blade fragments shall be incorporated in the design of the semicircular enclosure.

5.2.5 Lockout/Tagout procedures:

5.2.5.1 No employee shall be permitted to perform maintenance or repair activity on equipment (such as compressors, mixers, screens, or pumps used for concrete and masonry construction activities) where the inadvertent operation of the equipment could occur and cause injury, unless all potentially hazardous energy sources have been locked out and tagged.

5.2.5.2 Tags shall read Do Not Start or similar language to indicate that the equipment is not to be operated.

5.3—Requirements for cast-in-place concrete

5.3.1 General requirements for formwork:

5.3.1.1 Formwork shall be designed, fabricated, erected, supported, braced, and maintained so that it will be capable of supporting without failure all vertical and lateral loads that may reasonably be anticipated to be applied to the formwork.

5.3.1.2 Drawings or plans, including all revisions, for the jack layout, formwork (including shoring equipment), working decks, and scaffolds shall be available at the job site.

5.3.2 Shoring and reshoring:

5.3.2.1 All shoring equipment (including equipment used in reshoring operations) shall be inspected prior to erection to determine that the equipment meets the requirements specified in the formwork drawings.

5.3.2.2 Shoring equipment found to be damaged such that its strength is reduced to less than that required value shall not be used for shoring.

5.3.2.3 Erected shoring equipment shall be inspected immediately prior, during, and immediately after concrete placement.

5.3.2.4 Shoring equipment that is found to be damaged or weakened after erection, such that its strength is reduced to less than that required, shall be immediately reinforced.

5.3.2.5 The sills for shoring shall be sound, rigid, and capable of carrying the maximum intended load.

5.3.2.6 All base plates, shore heads, extension devices, and adjustment screws shall be in firm contact, and secured when necessary, with the foundation and the form.

5.3.2.7 Eccentric loads on shore heads and similar members shall be prohibited unless these members have been designed for such loading.

5.3.2.8 Adjustment of single post shores to raise forms shall not be made after the placement of concrete.

5.3.2.9 Reshoring shall be erected, as the original forms and shores are removed, whenever the concrete is required to support loads in excess of its capacity.

5.3.3 Vertical slip forms:

5.3.3.1 The steel rods or pipes on which jacks climb or by which the forms are lifted shall be:

(a) Specifically designed for that purpose; and
(b) Adequately braced where not encased in concrete.

5.3.3.2 Forms shall be designed to prevent excessive distortion of the structure during the jacking operation.

5.3.3.3 All vertical slip forms shall be provided with scaffolds or work platforms where employees are required to work or pass.

5.3.3.4 Jacks and vertical supports shall be positioned in such a manner that the loads do not exceed the rated capacity of the jacks.

5.3.3.5 The jacks or other lifting devices shall be provided with mechanical dogs or other automatic holding devices to support the slip forms whenever failure of the power supply or lifting mechanism occurs.

5.3.3.6 The form structure shall be maintained within all design tolerances specified for plumbness during the jacking operation.

5.3.3.7 The predetermined safe rate of lift shall not be exceeded.

5.3.4 Reinforcing steel:

5.3.4.1 Reinforcing steel for walls, piers, columns, and similar vertical structures shall be adequately supported to prevent overturning and to prevent collapse.

5.3.4.2 Employers shall take measures to prevent unrolled wire mesh from recoiling. Such measures may include, but are not limited to, securing each end of the roll or turning over the roll.

5.3.5 Removal of formwork:

5.3.5.1 Forms and shores (except those used for slabs on grade and slip forms) shall not be removed until the employer determines that the concrete has gained sufficient strength to support its weight and superimposed loads. Such determination shall be based on compliance with one of the following:

(a) The plans and specifications stipulate conditions for removal of forms and shores, and such conditions have been followed, or
(b) The concrete has been properly tested with an appropriate ASTM standard test method designed to indicate the concrete compressive strength, and the test results indicate that the concrete has gained sufficient strength to support its weight and superimposed loads.

5.3.5.2 Reshoring shall not be removed until the concrete being supported has attained adequate strength to support its weight and all loads in place upon it.

5.4—Inspection of formwork

5.4.1 Form inspection prior to casting shall include the following:

5.4.1.1 Forms shall be inspected and checked before the reinforcing steel is placed to confirm that the dimensions and the location of the concrete members will conform to the structural plans.

5.4.1.2 Blockouts, inserts, sleeves, anchors, and other embedded items shall be properly identified, positioned, and secured.

5.4.1.3 Forms shall be checked for required camber when specified in the contract documents or shown on the formwork drawings.

5.4.2 Inspection and Adjustment of Formwork

5.4.2.1 For Inspection and Adjustment, the following actions shall be taken before concrete placement:

(a) Telltale devices shall be installed on shores or forms to detect formwork movements during concrete placement.
(b) Wedges used for final alignment before concrete placement shall be secured in position before the final check.
(c) Forms shall be anchored to the shores below so that undesired movement of any part of the formwork system will be prevented during concrete placement. Such anchorages shall be installed in such a way as to allow for anticipated take-up, settlement, or deflection of the formwork members.
(d) Additional height of formwork shall be provided to allow for closure of form joints, settlements of mudsills, shrinkage of lumber, and elastic shortening and dead load deflections of form members. Where appropriate, the dimensional value of the expected shortening effects may be stated in the formwork design drawings.
(e) Positive means of adjustment (wedges or jacks) shall be provided to permit realignment or readjustment of shores if settlement occurs. Adjustment during or after concrete placement shall not be performed.

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PART II—CONCRETE

CHAPTER 6—SCOPE, DEFINITIONS AND REFERENCED STANDARDS

This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title, and the section or sections of this document that reference the standard. These standards are listed here for guidance; however, for enforcement, they shall be adopted and/or approved by the appropriate governmental authority (SASO or SBCNC) as per their mandates, before being considered part of this code.

6.1—Scope

6.1.1 This part of the code (Chapter 6 through Chapter 11) covers construction requirements for structural concrete including concrete mixtures, production and delivery, handling, placing and finishing, curing of concrete, hot and cold weather concreting.

6.2—Definitions

6.2.1 The following terms shall, for the purposes of this code, have the meanings shown below.

Approved—Determined to be satisfactory by Architect/ Engineer—The architect, engineer, architectural firm, engineering firm, or architectural and engineering firm issuing Project Drawings and Specifications, or supervising the Work under the Contract Documents.

Cold weather—A period when the average daily ambient temperature is below 4°C for more than three successive days. The average daily temperature is the average of the highest and lowest temperature during the period from midnight to midnight. When temperatures above 10°C occur during more than half of any 24-hour duration, the period shall no longer be regarded as cold weather.

Contract Documents—A set of documents supplied by Owner to Contractor as the basis for construction. These documents contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes.

Contractor—The person, firm, or corporation with whom the Owner enters into an agreement for construction of the Work.

Curing period—Time during which continuous curing procedures are employed. (Note: The curing period includes the initial and final curing stages.)

Day—A time period of 24 consecutive hours.

Dry—Having no visible liquid water.

Evaporation retardant—A material applied to the surface of concrete, before set, to reduce the evaporation rate of water without interfering with finishing operations.

Final curing—Deliberate action after the final finishing to reduce the loss of water from the surface of the concrete and control the temperature of the concrete.

Hot weather—High ambient temperature in combination with high concrete temperature, low relative humidity, high wind velocity, and solar radiation that may cause excessive evaporation.

Initial curing—Deliberate action taken between placement and final finishing of concrete to reduce the loss of water from the surface of the concrete.

Owner—The corporation, association, partnership, individual, or public body or authority with whom the Contractor enters into an agreement and for whom the Work is provided.

Quality assurance—Actions taken by Owner or Owner's Representative to provide confidence that Work done and materials provided are in accordance with Contract Documents.

Quality control—Actions taken by Contractor to ensure that Work meets the requirements in Contract Documents.

Permitted—Accepted by or acceptable to Architect/ Engineer, usually pertains to a request by Contractor, or when specified in Contract Documents.

Project drawings—The drawings, which along with the Project Specifications, complete the descriptive information for constructing the Work required or referred to in the Contract Documents.

Project specifications—The written documents which specify requirements for a project in accordance with the service parameters and other specific criteria established by the Owner.

Protection period—The required time during which the concrete is maintained at or above a specific temperature in order to prevent freezing of the concrete or to ensure the necessary strength development for structural safety.

Referenced standards—Standards of a technical society, organization, or association, including the codes of local or state authorities, which are referenced in the Contract Documents.

Required—Mandatory as prescribed in Project Specifications or Contract Documents.

Segregation—The tendency for coarse aggregate to separate from the sand-cement mortar.

Submit—Provide to Architect/Engineer for review.

Submittal—Document or material provided to Architect/ Engineer for review and approval

Testing agency—The person, firm, or entity under contract for testing.

Wet—Covered with visible free moisture; not dry.

Work—The entire construction or separately identifiable parts thereof which are required to be furnished under the Contract Documents. Work is the result of performing services, furnishing labor, and furnishing and incorporating materials and equipment into the construction, all as required by the Contract Documents.

6.3—Referenced standards

Standards cited in this Part of the Code are listed below with their titles and serial designations.

6.3.1 American Association of State Highway and Transportation Officials (AASHTO)

M 182 Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats

6.3.2 American Concrete Institute (ACI)

ACI 117M Specification for Tolerances for Concrete Construction and Materials

6.3.3 ASTM International

A820/A820M Standard Specification for Steel Fibers for Fiber-Reinforced Concrete.

C31/C31M Standard Practice for Making and Curing Concrete Test Specimens in the Field.

C33/C33M Standard Specification for Concrete Aggregates.

C39/C39M Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.

C78/C78M Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third- Point Loading).

C94/C94M Standard Specification for Ready-Mixed Concrete.

C138/C138M Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete.

C143/C143M Standard Test Method for Slump of Hydraulic-Cement Concrete.

C144 Standard Specification for Aggregate for Masonry Mortar.

C150/C150M Standard Specification for Portland Cement.

C156 Standard Test Method for Water Retention by Liquid Membrane-Forming Curing Compounds for Concrete.

C171 Standard Specification for Sheet Materials for Curing Concrete.

C173/C173M Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.

C192/C192M Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory.

C231/C231M Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method.

C293/C293M Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading).

C309 Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.

C387/C387M Standard Specification for Packaged, Dry, Combined Materials for Concrete and High Strength Mortar.

C404 Standard Specification for Aggregates for Masonry Grout.

C494/C494M Standard Specification for Chemical Admixtures for Concrete.

C618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.

C685/C685M Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing.

C845/C845M Standard Specification for Expansive Hydraulic Cement.

C989/C989M Standard Specification for Slag Cement for Use in Concrete and Mortars.

C1017/C1017M Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete.

C1064/C1064MStandard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete.

C1077 Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation.

C1116/C1116M Standard Specification for Fiber-Reinforced Concrete

C1218/C1218M Standard Test Method for Water-Soluble Chloride in Mortar and Concrete.

C1240 Standard Specification for Silica Fume Used in Cementitious Mixtures.

C1315 Standard Specification for Liquid Membrane- Forming Compounds Having Special Properties for Curing and Sealing Concrete.

C1602/C1602M Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete.

E1155 Standard Test Method for Determining FF Floor Flatness and FL Floor Levelness Numbers.

6.4—Quality assurance and quality control

6.4.1 Accredited testing agency (or agencies) meeting the requirements of Part III of this Code shall be employed to perform quality control testing.

6.4.2 Testing agencies that perform testing services shall be accepted by the Architect/Engineer before performing any Work.

6.4.3 The agency that perform testing services on concrete and concrete aggregates shall meet the requirements of ASTM C1077.

6.4.4 Field tests of concrete shall be made by an ACI Concrete Field Technician - Grade 1 or equivalent.

6.4.5 The testing agency shall report results of tests and inspections performed during the course of the work within 3 working days of testing.

6.4.6 An adequate area for use by the testing agency for safe storage of field-cured specimens until time of test shall be provided by the contractor.

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CHAPTER 7 —CONCRETE MIXTURES, PRODUCTION AND DELIVERY

7.1—General

7.1.1 Scope

7.1.1.1 This chapter covers the requirements for materials, proportioning, production, and delivery of concrete.

7.1.2 Definitions

7.1.2.1 Terms used in this Chapter are as defined in Chapter 6.

7.1.3 Referenced standards

7.1.3.1 Standards cited in this Chapter are listed in Chapter 6 with their titles and serial designations.

7.1.4 Submittals by the Contractor

7.1.4.1 Provide submittals as required by this Code in accordance with Contract Documents:

(a) Mixture proportions—Concrete mixture proportions and characteristics.

(b) Mixture strength data—Strength data records used to establish the required average strength in accordance with Section 7.2.3.5 .

(c) Concrete materials—The following information for concrete materials, along with evidence demonstrating compliance with Section 7.2.1:

(i) For cementitious materials: types, manufacturing locations, shipping locations, and certificates showing compliance with ASTM C150/C150M, ASTM C618, ASTM C845/C845M, ASTM C989/C989M, or ASTM C1240.

(ii) For aggregates: types, pit or quarry locations, producers' names, aggregate supplier statement of compliance with ASTM C33/C33M.

(iii) For admixtures: types, brand names, producers' names, manufacturer's technical data sheets, and certificates showing compliance with ASTM C494/C494M and ASTM C1017/C1017M.

(iv) For water and ice: source of supply, when nonpotable source is proposed for use, documentation on effects of water on strength and setting time in compliance with ASTM C1602/C1602M. Documentation on optional requirements of ASTM C1602/C1602M.

(d) Field test records—Data on material and mixture proportions with supporting test results if field test records are used as the basis for selecting proportions and documenting conformance with specified requirements, in accordance with Section 7.2.3.6 (a).

(e) Trial mixture records—Data on material and mixture proportions with supporting test results if trial mixture records are used as a basis for documenting compliance with specified requirements in accordance with Section 7.2.3.6 (b).

(f) Durability requirements—Documentation that concrete meets durability requirements of Section 7.2.2.6 .

(g) Mixture proportion adjustments—Requests for adjustments to mixture proportions or changes in materials made during the course of the Work, along with supporting documentation showing conformance with the Contract Documents.

(h) Volumetric batching—Request and description of method if concrete production by the volumetric batching method is proposed.

(i) Certification of production facilities and delivery vehicles—Documentation of certification or approval

7.1.5 Quality control and quality assurance

7.1.5.1 Quality assurance and Quality control shall comply with the requirements of Chapter 6, Section 6.4.

7.1.5.2 Test records shall be maintained verifying that materials used are the specified and accepted types and sizes and are in conformance with Section 7.2.1.

7.1.5.3 Production and delivery of concrete shall conform to Sections 7.3.1 and 7.3.2.

7.1.5.4 Concrete shall have the specified characteristics in the freshly mixed state at delivery

7.1.6 Material storage and handling

7.1.6.1 Cementitious materials—Cementitious materials shall be kept dry and free from contaminants.

7.1.6.2 Aggregates—Aggregate shall be stored and handled in a manner that will avoid segregation and prevents contamination by other materials or other sizes of aggregates. Store aggregates in locations that will permit them to drain freely.

7.1.6.3 Water and ice—Mixing water and ice shall be protected from contamination during storage and delivery.

7.1.6.4 Admixtures—Admixtures shall be protected against contamination, evaporation, or damage. To ensure uniform distribution of constituents, provide agitating equipment for admixtures used in the form of suspensions or unstable solutions. Liquid admixtures shall be protected from temperature changes that would adversely affect their characteristics.

7.2—Concrete mixtures

7.2.1 Materials

7.2.1.1 Cementitious materials—Unless otherwise specified, cementitious materials shall conform to Sections 7.2.1.1 (a) through 7.2.1.1 (e). Use cementitious materials that meet the durability criteria of Section 7.2.2.6 .

(a) Portland cement conforming to ASTM C150.
(b) Pozzolans conforming to ASTM C618.
(c) Slag cement conforming to ASTM C989/C989M.
(d) Silica fume conforming to ASTM C1240.
(e) Cementitious materials used shall be of same brand and type and from same manufacturing plant as cementitious materials used in concrete represented by submitted field test records or used in trial mixtures.

7.2.1.2 Aggregates—Unless otherwise specified, aggregates shall conform to ASTM C33/C33M. Aggregates used in concrete shall be obtained from the same sources and have the same size range as aggregates used in concrete represented by submitted field test records or used in trial mixtures.

7.2.1.3 Water and ice—Unless otherwise specified, mixing water for concrete and water used to make ice shall comply with ASTM C1602/C1602M.

7.2.1.4 Admixtures—Unless otherwise specified, admixtures shall conform to the following:

(a) Chemical admixtures conforming to ASTM C494/C494M.
(b) Chemical admixtures for use in producing flowing concrete conforming to ASTM C1017/C1017M.
(c) Admixtures used in concrete shall be the same as those used in the concrete represented by submitted field test records or used in trial mixtures.

7.2.1.5 Steel fibers—If steel fiber-reinforced concrete is specified in Contract Documents for providing shear resistance, steel fibers shall be deformed and conform to ASTM A820/A820M. Steel fibers shall have a length-to-diameter ratio of at least 50 and not exceed 100. Steel fibers for other applications shall be in accordance with Contract Documents.

7.2.1.6 Change of materials—If changes to brand, type, size, or source of cementitious materials; aggregates; water; ice; or admixtures are proposed, submit new field data, data from new trial mixtures, or other evidence that the change will not adversely affect the relevant properties of the concrete. Data shall be submitted before changes are made.

7.2.2 Performance and design requirements

7.2.2.1 Cementitious material content—Cementitious material content shall be adequate for concrete to satisfy the specified requirements for strength, w/cm, durability, and finishability.

7.2.2.2 Slump—Unless otherwise specified, select a target slump at the point of delivery for all concrete mixtures not to exceed 150 mm. Concrete shall not show visible signs of segregation. Slump shall be determined in accordance with ASTM C143/C143M.

7.2.2.3 Size of coarse aggregate—Unless otherwise specified, nominal maximum size of coarse aggregate shall not exceed three-fourths of the minimum clear spacing between reinforcement, one-fifth of the narrowest dimension between sides of forms, or one-third of the thickness of slabs or toppings.

7.2.2.4 Air content—Non-air entrained concrete shall be used with the total air content not to exceed

3%. Air content shall be measured in accordance with ASTM C173/C173M or ASTM C231.

7.2.2.5 Concrete temperature

(a) Minimum temperature—If the average of the highest and lowest ambient temperature from midnight to midnight is expected to be less than 4°C for more than 3 successive days, comply with cold weather requirements of Chapter 11 of the Code.

(b) Maximum temperature—Unless otherwise specified, the temperature of concrete as delivered shall not exceed 35°C.

7.2.2.6 Durability

(a) Sulfate resistance—Unless otherwise specified, provide concrete meeting the requirements of Table 7-1, based on the exposure class assigned to members for sulfate exposure. Submit documentation verifying compliance with specified requirements.

(b) Corrosion protection of reinforcement—Unless otherwise specified, concrete shall meet the requirements of Table 7-2 based on the exposure class assigned to members requiring protection against reinforcement corrosion in Contract Documents. Documentation shall be submitted verifying compliance with specified requirements. Water-soluble chloride ion content contributed from constituents including water, aggregates, cementitious materials, and admixtures shall be determined for the concrete mixture by ASTM C1218/C1218M at age between 28 and 42 days.

7.2.2.7 Strength and w/cm—The compressive strength and maximum w/cm of the concrete for each portion of the Work, shall be as specified in Contract Documents.

(a) Unless otherwise specified, strength requirements shall be based on compressive strength tests at 28 days. Compressive strength is measured using 150 x 300 mm or 100 x 200 mm cylindrical specimens made and tested in accordance with ASTM C31/C31M and C39/C39M, respectively. A strength test at designated age is the average of at least two 150×300 mm cylinders or the average of at least three 100×200 mm cylinders made from the same concrete sample.

7.2.2.8 Steel fiber-reinforced concrete—If steel fiber-reinforced concrete is specified for providing shear resistance, the concrete mixture shall conform to ASTM C1116/C1116M. Unless otherwise specified, the mixture shall contain at least 60 kg. of steel fibers per cubic meter of concrete and shall meet the requirements of Section 26.12.5 of SBC 304. Steel fiber-reinforced concrete for other applications shall be in accordance with Contract Documents.

7.2.3 Proportioning

7.2.3.1 Concrete shall be proportioned to comply with Section 7.2.2 and so concrete can be worked readily into forms and around reinforcement without segregation, and to provide an average compressive strength adequate to meet acceptance requirements of Chapter 26 of SBC 304.

7.2.3.2 If the production facility has records of field strength tests performed within the past 12 months and spanning no less than 45 calendar days for a class of concrete within 7 MPa of that specified for Work, a sample standard deviation shall be calculated in accordance with Section 7.2.3.4 and the required average compressive strength f'_{cr} established in accordance with Section 7.2.3.5 (a).

7.2.3.3 If reliable field strength test records are not available, f'_{cr} shall be determined from Table 7-3.

7.2.3.4 Sample standard deviation

(a) Field strength test records—Field strength test records used to calculate sample standard deviation shall represent materials, mixture proportions, quality control procedures, and climatic conditions similar to those expected in the Work. Test records shall comply with data from a single group of at least 30 consecutive compressive-strength tests with the same mixture proportions.

(b) Calculation of sample standard deviation - The sample standard deviation S_s of the strength test records shall be calculated as follows:

$$S_s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{(n-1)}} \qquad \textbf{(7-1)}$$

where S_s is sample standard deviation; n is number of test results considered; $\bar{X}$ is average of n test results considered; and X_i is individual test result

7.2.3.5 Required average compressive strength - f'_{cr} shall be determined for specified class of

concrete in accordance with Section 7.2.3.5 (a) or Section 7.2.3.5 (b).

(a) The sample standard deviation calculated in accordance with Section 7.2.3.4 shall be used to establish f'_{cr} in accordance with Table 7-4. Use larger of two values of f'_{cr} calculated.

(b) When field strength test records are not available to calculate a sample standard deviation, the required average compressive strength f'_{cr} shall be determined from Table 7-4.

7.2.3.6 Documentation of average compressive strength—Provide documentation indicating the proposed concrete proportions will produce an average compressive strength equal to or greater than the required average compressive strength. Documentation shall consist of field strength test records in accordance with Section 7.2.3.6 (a) or trial mixtures in accordance with Section 7.2.3.6 (b).

(a) Field strength test data—If field strength test data are available and represent a single group of at least 30 consecutive strength tests for one mixture, using the same materials, under the same conditions, and encompassing a period of not less than 45 days, the average of field strength test results equals or exceeds f'_{cr} shall be verified.

(b) Trial mixtures—Mixture proportions shall be established based on trial mixtures to comply with the following:

(i) Materials and materials combinations listed in Sections 7.2.1.1 through 7.2.1.4 proposed for the Work shall be used.

(ii) f'_{cr} shall be determined in accordance with Section 7.2.3.5 .

(iii) At least three trial mixtures shall be made for each concrete class with a range of proportions that will produce a range of compressive strengths that will encompass f'_{cr}. For concrete made with more than one type of cementitious material, the concrete supplier shall establish the w/cm and the relative proportions of the cementitious materials and admixtures, if any, that will produce the required average compressive strength.

(iv) Trial mixtures shall be proportioned to produce a slump as specified for proposed Work.

(v) For each trial mixture, three compressive strength cylinders shall be made and cured for each test age in accordance with ASTM C192/C192M. Compressive strength shall be tested in accordance with ASTM C39/C39M at 28 days or at the designated test age for f'_c.

(vi) Mixture proportions shall be established based on the trial batch data to achieve an average compressive strength of at least f'_{cr} as determined in Section 7.2.3.5 and to not exceed maximum w/cm. The proposed concrete mixture shall meet other applicable requirements of Section 7.2.2.6 and trial mixture records shall have been developed less than 12 months from the date of submittal.

7.2.3.7 Field verification of selected mixture proportions—If required by the Engineer, field verification of the effects of placement methods on concrete mixture characteristics shall be conducted. Using materials and mixture proportions accepted for use in the Work, verify that concrete can be placed using the intended placing method. Place concrete mixture using project equipment and personnel. Evaluate the effect of placement methods on slump. Make suitable corrections to the placing methods or to mixture proportions, if needed. Submit adjustments to mixture proportions.

7.2.3.8 Revisions to concrete mixtures—When 30 consecutive compressive strength test results become available from the field, calculate the average compressive strength and standard deviation. A revised value for f'_{cr} shall be calculated in accordance with Section 7.2.3.5 (a).

(a) If actual average compressive strength $\bar{X}$ exceeds the revised value of f'_{cr} and requirements of Chapter 26 of SBC 304 are met, it is acceptable to modify mixture proportions to achieve an average strength equal to the revised value of f'_{cr}. The revised mixture shall meet requirements of Section 7.2.2.

(b) If actual average compressive strength $\bar{X}$ is less than revised value of f'_{cr} or if either of the two requirements in Section 26.12.3 of SBC 304 is not met, immediate steps shall be

taken to increase average compressive strength of the concrete.

(c) Revised mixture proportions for approval shall be submitted before placing the revised concrete in the Work.

7.3—Production and delivery of concrete

7.3.1 Measuring, batching, and mixing— Production facilities shall produce concrete of specified quality and conforming to this Code.

7.3.1.1 Ready mixed concrete—Unless otherwise specified, measure, batch, and mix concrete materials and concrete in conformance to ASTM C94/C94M.

7.3.1.2 Concrete produced by volumetric batching and continuous mixing—Concrete produced by volumetric batching and continuous mixing shall conform to ASTM C685/C685M.

7.3.1.3 Prepackaged dry materials used in concrete—If packaged dry-combined materials are used, they shall conform to ASTM C387/C387M and satisfy requirements of this Code.

7.3.2 Delivery

7.3.2.1 Concrete shall be transported and delivered in equipment conforming to ASTM C94/C94M.

7.3.2.2 Slump adjustment—Unless otherwise specified, if concrete slump test results are below required slump, slump may be adjusted by adding chemical admixtures. Measure slump after slump adjustment to verify compliance with specified requirements. Adding water to increase slump shall not be allowed.

7.3.2.3 Limits on discharge—Discharge of concrete shall be completed within 120 minutes after the introduction of mixing water to the cement and aggregate. Slump and temperature of concrete shall be within the specified limits.

7.3.2.4 Sampling for compliance testing— Samples for preparing strength test specimens of each concrete mixtures shall comply with the requirements of Section 26.12.2 of SBC 304.

TABLES OF Chapter 7

Table 7-1: Requirements for Exposure Category S: Sulfate exposure

Exposure class	Maximum w/cm	Minimum f'_c MPa	Cement type
S0	N/A	20	No type restriction
S1	0.50	28	II or V
S2	0.45	31	V
S3	0.45	31	V + pozzolan or slag cement

Table 7-2: Requirements for Exposure Category C: Conditions requiring corrosion protection of reinforcement

Exposure class	Maximum w/cm	Minimum f'_c, MPa	Cement type	Maximum water-soluble chloride ion (Cl-) content in concrete, percent by weight of cement	
				Nonpre-stressed concrete	Pre-stressed concrete
C0	N/A	20	No type restriction	1.00	0.06
C1	0.50	28	No type restriction	0.30	0.06
C2	0.50	28	No type restriction	0.15	0.06
C3	0.45	31	I or II	0.15	0.06
C4	0.40	35	I + pozzolan or Slag cement	0.15	0.06
C5	0.35	40	I + pozzolan or Slag cement	0.15	0.06

Table 7-3: Required average compressive strength f'_{cr} when data are not available to establish standard deviation

Specified compressive strength, f'_c, MPa	Required average compressive strength, f'_{cr}, MPa
20 to 35	$f'_c + 8.5$
Over 35	$1.1\, f'_c + 5$

Table 7-4: Required average compressive strength f'_{cr} when data are available to establish a sample standard deviation, MPa

Specified compressive strength f'_c, MPa	Required average compressive strength, f'_{cr}, MPa
	Use the larger of:
35 or less	$f'_{cr} = f'_c + 1.347\, S_s$
	$f'_{cr} = f'_c + 2.33\, S_s - 3.5$
Over 35	$f'_{cr} = f'_c + 1.341\, S_s$
	$f'_{cr} = 0.90\, f'_c + 2.331\, S_s$

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CHAPTER 8—HANDLING, PLACING AND FINISHING

8.1—General

8.1.1 Scope

8.1.1.1 This chapter covers the construction of cast-in-place structural concrete. Included are procedures for handling, placing, finishing, and repair of surface defects.

8.1.2 Definitions

8.1.2.1 Terms used in this Chapter are as defined in Chapter 6.

8.1.3 Referenced standards

8.1.3.1 Standards cited in this Chapter are listed in Chapter 6 with their titles and serial designations.

8.1.4 Submittals by the Contractor

8.1.4.1 The Contractor shall submit to the Architect/Engineer the information specified in Sections 8.1.4.1 (a) through 8.1.4.1 (d) unless otherwise specified.

(a) Placement notification—Notification of concrete placement at least 24 hours before placement.
(b) Preplacement requirements—List of preplacement activities.
(c) Preplacement meeting—Agenda for preplacement meeting to be held before start of placement activities.
(d) Hot-weather placement—Comply with Chapter 10 of this Code for hot weather placement and protection requirements

8.1.4.2 If required, the Contractor shall submit information specified in Sections 8.1.4.2 (a) through 8.1.4.2 (e).

(a) Conveying equipment—Description of conveying equipment.
(b) Surface cleaning—If removal of stains, rust, efflorescence, and surface deposits is required as described in Section 8.3.7.6 , submit proposed method of removal.
(c) Wet-weather protection—Wet-weather protection activities.
(d) Cold-weather placement and protection activities - Comply with Chapter 11 of this Code for cold-weather placement requirements, temperature-measuring methods, and protection activities.
(e) Initial curing—Comply with Chapter 9 for methods to be used for initial curing.

8.1.4.3 If alternatives are proposed, comply with Sections 8.1.4.3 (a) through 8.1.4.3 (d) for approval.

(a) Bonding agent—If bonding material other than cement grout is proposed for two-course slabs or construction joints, applicable specification and manufacturer's data on bonding agent shall be submitted.
(b) Contraction or expansion joints—If contraction or expansion joints other than those indicated in Contract Documents are proposed, locations shall be submitted.
(c) Repair materials—If a repair material other than that described in Section 8.2.1.1 is proposed, applicable repair material specification, manufacturer's data on the proposed repair material, and proposed preparation and application procedure shall be submitted.
(d) Sawed joints—If sawed joints are to be installed using methods that are different from those specified in Section 8.3.5, request of the proposed methods shall be submitted.

8.1.4.4 Joints not shown in Contract Documents

(a) The Contractor shall submit details and locations of construction joints not indicated in Contract Documents, for approval.
(b) Location of construction joints shall be in accordance with the following requirements:

(i) Joints shall be located within middle one-third of spans of slabs, beams, and girders. If a beam intersects a girder within the middle one-third of girder span, the distance between the construction joint in the girder and the edge of the beam shall be at least twice the width of the larger member.
(ii) For members with post-tensioning tendons, joints shall be located where tendons pass through centroid of concrete section.
(iii) Joints in walls and columns shall be located at underside of slabs, beams,

or girders and at tops of footings or slabs.

(iv) Joints shall be made perpendicular to main reinforcement.

8.1.5 Delivery, storage, and handling

8.1.5.1 Delivery, storage, and handling of products shall be in accordance with manufacturer's recommendations.

8.1.5.2 Products stored beyond manufacturer's recommended shelf life shall not be used.

8.2—Products

8.2.1 Materials

8.2.1.1 Surface repair materials—Unless otherwise specified, approved repair mortar shall be used to repair surface defects. For concrete exposed to view, repair mortar shall match adjacent concrete color.

8.2.1.2 Bonding material—Approved bonding agent applied in accordance with the manufacturer's requirements or Portland-cement grout of the same proportions as the mortar in the concrete shall be used.

8.2.1.3 Scrub coat—Scrub coat material shall be mixed with one part Portland cement and one part sand by loose volume with water. Sand shall meet the requirements of ASTM C144 or ASTM C404.

8.3—Execution

8.3.1 Preparation

8.3.1.1 Concrete shall not be placed until data on materials and mixture proportions are approved.

8.3.1.2 Hardened concrete and foreign materials from inner surfaces of conveying equipment shall be removed.

8.3.1.3 Before placing concrete in forms, the following shall be completed:

(a) Comply with formwork requirements specified in PART I of this Code.

(b) Remove water, debris and other foreign materials from surfaces against which concrete will be placed, and from reinforcement and embedded items.

(c) Comply with reinforcement placement requirements specified in the Design Documents.

8.3.1.4 Before placing a concrete slab-on-ground, remove foreign materials from the subgrade and verify compliance with the following:

(a) Subgrade and base shall be prepared in accordance with Contract Documents.

(b) Tolerance for the base material elevation shall be in accordance with ACI 117M.

8.3.1.5 In hot weather, provisions shall be made in advance of concrete placement to limit the rate of evaporation of water from the concrete surface during or immediately after placing or finishing, as detailed in Chapter 9 and Chapter 10 of this Code.

8.3.1.6 In cold weather, the concrete shall be cured and protected in accordance with the requirements of Chapter 11. Use heating, covering, or other means to maintain required temperature without drying of concrete.

8.3.2 Placement of concrete

8.3.2.1 Surfaces against which concrete will be placed shall be prepared to minimize the absorption of water from the fresh concrete. Concrete shall not be placed against surfaces that will introduce free water to the fresh concrete.

8.3.2.2 Weather considerations

(a) Wet weather—Concrete shall not be placed while rain is falling unless protection is provided. Do not allow precipitation to increase mixing water or to damage concrete surface.

(b) Cold weather—Concrete temperatures at delivery and placing shall meet the requirements of Chapter 11. Do not place concrete in contact with surfaces less than 2°C. Unless otherwise specified, this requirement shall not apply to reinforcing steel.

(c) Hot weather—Unless otherwise specified, concrete temperature as placed shall not exceed 35°C. If temperature of reinforcement, embedments, or forms is greater than 50°C, use a fine mist of water to moisten and cool hot surfaces. Standing water shall be removed before placing concrete.

8.3.2.3 Conveying - Concrete shall be conveyed from mixer to final deposition using equipment in Section 8.3.2.4 by methods that do not result in segregation or loss of constituents.

8.3.2.4 Conveying equipment - Conveying equipment used shall be of sufficient capacity to meet the requirements of Section 8.3.2.3 . Conveying equipment in contact with concrete shall not be made of aluminum.

(a) Use belt conveyors with a discharge baffle or hopper at discharge end. Slope of conveyors shall not cause segregation on belt.
(b) Use metal or metal-lined chutes having rounded bottoms, and sloped between 1:2 and 1:3. Chutes longer than 6 m and chutes not meeting slope requirements may be used provided discharge is into a hopper before distributing into forms.
(c) Use pumping equipment that has sufficient capacity so that:

(i) Discharge of pumped concrete does not result in segregation.
(ii) Modification of approved concrete mixture is not required.

8.3.2.5 Depositing

(a) Deposit concrete continuously and as near as practicable to the final position.
(b) Deposit concrete in one layer or in multiple layers as approved. Fresh concrete shall not be placed against concrete that would result in cold joints unless construction joint requirements of Section 8.3.2.7 are met.
(c) Concrete that contains foreign materials shall not be used.
(d) Concrete over columns or walls shall not be placed until concrete in columns and walls has reached final setting.
(e) Do not subject concrete to procedures that will cause segregation.
(f) Concrete for beams, girders, brackets, column capitals, haunches, and drop panels shall be placed at same time as concrete for adjacent slabs.
(g) If underwater placement is required, place concrete by an approved method. Fresh concrete shall be deposited so concrete enters the mass of previously placed concrete and not in contact with the water.

8.3.2.6 Consolidating

(a) Unless otherwise specified, concrete shall be consolidated by vibration. Consolidate concrete around reinforcement, embedded items, and into corners of forms.
(b) Use immersion-type vibrators with nonmetallic heads for consolidating concrete around epoxy-coated reinforcing bars. Do not use vibrators to move concrete in a manner that will result in segregation. Spacing of immersion vibrator insertions shall not exceed 1 1/2 times the vibrator's radius of action in concrete being consolidated.

8.3.2.7 Construction and movement joints—Install construction and movement joints in accordance with approved locations and details.

8.3.2.8 Remove laitance and thoroughly clean and dampen construction joints before placement of fresh concrete. If bond is required, use one of the following methods:

(a) Use a bonding material in accordance with Section 8.2.1.2 .
(b) Roughen surface in an acceptable manner that exposes coarse aggregate and does not leave laitance, loosened aggregate particles, or damaged concrete at surface.

8.3.3 Finishing formed surfaces

8.3.3.1 General—After form removal, each formed surface shall be given one or more of the finishes described in Sections 8.3.3.2 , 8.3.3.3 , or 8.3.3.5 . If Contract Documents do not specify a finish, finish surfaces as required by Section 8.3.3.4 .

8.3.3.2 Matching sample finish—If required to match a sample panel furnished to Contractor, reproduce a mockup of the sample finish on an area at least 9 m^2 in a location designated by Architect/Engineer in Contract Documents. Mockup shall be protected from damage for duration of project. Contractor shall obtain approval of mockup before proceeding with that finish in specified locations.

8.3.3.3 As-cast finishes—Use form-facing materials meeting the requirements of Part I of this Code. Unless otherwise specified, produce as-cast formed finishes to comply with Sections 8.3.3.3 (a), 8.3.3.3 (b), or 8.3.3.3 (c).

(a) Surface finish-1.0 (SF-1.0):
  (i) No formwork facing material is specified
  (ii) Patch voids larger than 40 mm wide or 13 mm deep
  (iii) Remove projections larger than 25 mm
  (iv) Tie holes need not be patched
  (v) Surface tolerance Class D as specified in ACI 117M
  (vi) Mockup not required
(b) Surface finish-2.0 (SF-2.0):
  (i) Patch voids larger than 20 mm wide or 13 mm deep
  (ii) Remove projections larger than 6 mm

(iii) Patch tie holes
(iv) Surface tolerance Class B as specified in ACI 117M.
(v) Unless otherwise specified, provide mockup of concrete surface appearance and texture

(c) Surface finish-3.0 (SF-3.0):
(i) Patch voids larger than 20 mm wide or 13 mm deep
(ii) Remove projections larger than 3 mm
(iii) Patch tie holes
(iv) Surface tolerance Class A as specified in ACI 117M.
(v) Provide mockup of concrete surface appearance and texture

8.3.3.4 Unspecified as-cast finishes—If a surface finish is not specified, the following finishes shall be provided:

(a) SF-1.0 on concrete surfaces not exposed to view
(b) SF-2.0 on concrete surfaces exposed to view

8.3.3.5 Architectural finishes—Produce architectural finishes in accordance with Contract Documents.

8.3.4 Finishing unformed surfaces

8.3.4.1 Finisher qualifications—Unless otherwise specified, at least one finisher or finishing supervisor shall be a certified ACI Flatwork Concrete Finisher/Technician or a certified ACI Flatwork Technician or equivalent.

8.3.4.2 Finishes and tolerances—Unformed surfaces shall receive the applicable finishes in Sections 8.3.4.3 (a) through 8.3.4.3 (d). If finish is not specified, finish surfaces as required by Section 8.3.4.3 (e).

8.3.4.3 If applicable, allow for the measurement of finishes of slab surfaces in accordance with ASTM E1155 and slab elevation to verify compliance with the tolerance requirements within 72 hours after slab finishing for slabs-on-ground and before stressing post-tensioning reinforcement, removing supporting formwork or shoring for elevated slabs.

(a) Scratch finish—Place, consolidate, strike off, and level concrete; cut high spots; and fill low spots. Roughen the surface with stiff brushes or rakes before concrete becomes too stiff to brush or rake.
(b) Float finish—Place, consolidate, strike off, and level concrete; cut high spots; and fill low spots. Do not perform further finishing operations until concrete is ready for floating. Begin floating with hand float, bladed power float equipped with float shoes, or powered disk float when bleed water sheen has disappeared and surface has stiffened sufficiently to permit operation of the specific float apparatus. Unless otherwise specified, produce a finish that will meet tolerance requirements of ACI 117M for a conventional surface.
(c) Trowel finish—Float concrete surface, then trowel the surface. Unless otherwise specified, tolerances for concrete floors shall be for a flat surface in accordance with ACI 117M. Addition of water to surface to facilitate finishing is prohibited.
(d) Broom or belt finish—After concrete has received float finish, give concrete surface a coarse-scored texture by drawing a broom or burlap belt across the surface.
(e) Unspecified unformed surface finishes—If finish is not specified, apply the following finishes to unformed concrete surface:
(i) Scratch finish—For surfaces intended to receive bonded cementitious or setting beds
(ii) Float finish—For walks; steps; and for surfaces intended to receive waterproofing, roofing, insulation, or sand-bed terrazzo
(iii) Trowel finish—For interior floors
(iv) Broom finish—For parking slabs and exterior surfaces, including slabs, ramps, walkways, and steps

8.3.5 Sawed joints

8.3.5.1 Where saw-cut joints are required, start cutting as soon as concrete has gained sufficient strength to prevent dislodgment of coarse aggregate particles. Do not saw cut reinforcement.

8.3.5.2 Unless otherwise specified, saw a continuous slot to a depth one-fourth the thickness of the slab but not less than 25 mm.

8.3.6 Curing and protection

8.3.6.1 Curing and protection of concrete shall comply with the requirements in Chapter 9 of the Code.

8.3.7 Repair of surface defects

8.3.7.1 General—Repair tie holes and other surface defects in formed finishes in accordance with the requirements of Section 8.3.3 unless otherwise specified. Where the concrete surface

will be textured by sandblasting or bush-hammering, repair surface defects before texturing.

8.3.7.2 Repair of tie holes—Unless otherwise specified, patch tie holes. If portland-cement repair mortar conforming to Section 8.3.7.4 is used for patching, clean and dampen tie holes before applying mortar. If other materials are used, they shall be applied in accordance with manufacturer's recommendations.

8.3.7.3 Repair of surface defects other than tie holes—Unless otherwise specified, surface defects shall be repaired by the following method:

(a) Outline repair area with a 15 mm deep saw cut and remove defective concrete down to sound concrete. Leave chipped edges perpendicular to the saw-cut surface or slightly undercut. Do not feather edges.

(b) Dampen the area to be patched plus 150 mm around the patch area perimeter. Prepare scrub coat according to Section 8.2.1.3 . Thoroughly brush scrub coat into the surface.

(c) When the scrub coat begins to lose water sheen, apply patching mortar prepared in accordance with Section 8.3.7.4 and thoroughly consolidate mortar into place. Strike off mortar, finishing flush to the final surface. Leave the patch undisturbed for 1 hour before finishing. Keep the patch damp for 7 days.

8.3.7.4 Site-mixed Portland-cement repair mortar—For surface repairs in concrete exposed to view, a trial batch shall be made to check color compatibility of repair material with surrounding concrete.

8.3.7.5 Repair materials other than site-mixed Portland cement mortar—Approved alternative repair material shall be used.

8.3.7.6 Removal of stains, rust, efflorescence, and surface deposits—Where required, use acceptable methods to remove stains, rust, efflorescence, and surface deposits.

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CHAPTER 9—CURING

9.1—General

9.1.1 Scope

9.1.1.1 This Chapter covers requirements for curing the cast-in-place concrete elements including requirements for initiating curing, curing for unformed and formed surfaces, curing time and protection from mechanical injury.

9.1.1.2 This Chapter does not cover curing of special concrete such as precast concrete and special construction techniques, or other concrete elements that require the use of special curing procedures.

9.1.2 Definitions

9.1.2.1 Terms used in this chapter are as defined in Chapter 6.

9.1.3 Referenced standards

9.1.3.1 Standards cited in this Chapter are listed in Chapter 6 with their titles and serial designations.

9.1.4 Submittals by the Contractor

9.1.4.1 Qualification test data on curing materials to be used shall be submitted by the Contractor as required by the Architect/Engineer for review and approval.

9.1.4.2 Submittals to the Architect/Engineer shall be forwarded a minimum of 7 days before execution of the Work unless otherwise specified.

9.1.4.3 No concrete shall be placed until the Architect/Engineer has accepted the curing materials.

9.1.4.4 The submittal shall cover the following curing materials if specified in the contract or proposed to be used by the Contractor:

(a) Fogging equipment: Submit proposed fogging equipment specifications.
(b) Sheet material: Submit proposed sheet material specifications. Specifications shall meet the requirements of ASTM C171.
(c) Liquid membrane-forming curing compound: Submit proposed liquid membrane-forming curing compound specifications. Specifications shall meet the requirements of ASTM C309 or ASTM C1315. Silicate-based liquid surface densifiers are prohibited as curing compounds.
(d) Water: Submit proposed water source.
(e) Dike material: Submit description of proposed dike material.
(f) Absorbent materials: Submit description of proposed absorbent material(s).
(g) Watering equipment: Submit proposed watering equipment specifications.
(h) Insulation materials: Submit proposed insulation material(s) specifications.
(i) Heating equipment: Submit proposed heating equipment specifications.
(j) Evaporation retardant: Submit proposed liquid applied evaporation retardant specifications.

9.1.4.5 Curing procedures: Procedures for curing including curing procedures for hot or cold weather anticipated during construction shall be submitted at least 1 month before concreting.

9.1.5 Quality assurance and quality control

9.1.5.1 Quality assurance and quality control shall comply with the requirements of Section 6.4 in Chapter 6.

9.1.5.2 The Contractor shall arrange for concrete curing materials and procedures to be tested and inspected at the start of the work.

9.1.5.3 The Contractor shall arrange for additional testing of curing materials and procedure as work progresses to verify adequacy if required by the Owner.

9.2—Products

9.2.1 Materials and physical protection

9.2.1.1 Liquid membrane-forming curing compound:

(a) Liquid membrane-forming curing compounds shall meet the requirements of ASTM C309 or ASTM C1315.
(b) White pigmented curing compounds shall be used when the concrete to be cured is exposed to the sun.

9.2.1.2 Evaporation retardants:

(a) Liquid applied evaporation retardants shall be used that form a thin continuous film (monomolecular film) and prevent rapid moisture loss of water from the plastic concrete surface.
(b) Evaporation retardant shall be applied in accordance with manufacturer's recommendations.

9.2.1.3 Sheet material: Sheet material shall meet the requirements of ASTM C171, unless otherwise specified.

9.2.1.4 Temperature protection: Protective blankets, enclosures, and various sources of heat input shall be provided, as required.

9.2.1.5 Wind protection: Wind screens shall be provided as required.

9.2.2 Water application

9.2.2.1 Water for curing

(a) Water used for curing shall be free of materials that have the potential to stain concrete or are known to cause deterioration of concrete or reinforcing steel.

9.2.2.2 Ponding

(a) Earth, clay, sand, or other acceptable material shall be used to build a dike around the area to be flooded.

9.2.2.3 Sprinkling systems: Use soaker hoses, lawn sprinklers, or a combination thereof.

9.2.2.4 Fogging systems:

(a) Use Equipment that produces a fog spray from atomizing nozzles that will uniformly cover the concrete surface. The minimum rate of fog application shall not be less than 400 $L/h/m^2$ to prevent evaporation of water from the concrete surface and the accumulation of standing water on the surface.
(b) The frequency of fogging and number of nozzles operating shall be dependent upon the environmental conditions.

9.2.2.5 Absorbent materials: An absorbent material shall be selected that will not adversely affect the concrete finish specified in the Contract Documents as follow.

(a) Earth materials shall be free of organic matter and particles larger than 25 mm.
(b) Burlap shall meet the requirements of AASHTO M 182.

9.3—Execution

9.3.1 Initial curing

9.3.1.1 Under conditions specified by the Contract Documents, concrete shall be cured immediately after placement by method (a) or (b) until final curing method is applied.

(a) Fogging:
  (i) Fogging equipment shall be set up to allow complete coverage of the area to be cured.
  (ii) The relative humidity above the slab shall be maintained at a level to prevent surface drying and the accumulation of standing water on the surface.
  (iii) Direct atomized water spray above the concrete surface to allow the fog to drift down to the concrete surface. Fogging shall be continued as necessary to maintain the reflective appearance of the damp concrete.
  (iv) Concrete surfaces shall be kept continuously damp, but accumulation of water shall not be allowed until after final setting of concrete has occurred.
(b) Evaporation retardant:
  (i) Bleed water on the concrete surface shall be entrapped under a uniform film of a liquid applied evaporation retardant.
  (ii) Evaporation retardant shall be applied in accordance with manufacturer's recommendations.
  (iii) Apply the evaporation retardant after strike off and between the different floating operations.
  (iv) Evaporation retarder shall not be used as an aid for subsequent finishing operations and texturing.

9.3.1.2 Liquid membrane-forming curing compounds shall not be used for initial curing purposes.

9.3.2 Final curing

9.3.2.1 Unformed concrete shall be cured after final finishing by one or more of the curing methods in Section 9.3.3 until termination of curing is allowed by Section 9.3.4.

9.3.2.2 Formed concrete

(a) After formwork has been loosened or removed, concrete shall be cured by one or

more of the curing methods in Section 9.3.3 until termination of curing is allowed by Section 9.3.4.

(b) When absorbent wood forms are used, they shall be kept wet until removed.

(c) The duration that forms remained tightly in place can be included in the duration of curing.

9.3.2.3 Curing by method in Section 9.3.3.5 shall be allowed only after approval by the Architect/ Engineer of the qualification testing on prototype performed at the Project site.

9.3.2.4 The finished concrete surface shall not be marred, damaged or discolored with any curing procedure.

9.3.3 Curing methods

9.3.3.1 Ponding:

(a) Build a dike of earth, sand, or other material around the concrete and flood the surface with water.

(b) The temperature of the water used shall not be more than 10°C cooler than the surface temperature of the concrete at the time the water and concrete come in contact.

(c) Start ponding on the concrete surface as soon as possible without marring the surface.

(d) Replace water lost due to evaporation or leakage at a rate sufficient to maintain the pond.

(e) The entire surface shall remain covered with water for the duration of the curing period.

(f) Alternate wetting and drying of the concrete surfaces shall not be permitted.

9.3.3.2 Continuous Sprinkling:

(a) Perform continuous sprinkling for final curing by using either soaker hoses or lawn sprinklers.

(b) Care shall be taken in sprinkling operation so the surface of the concrete is not eroded by running water.

(c) Using soaker hoses for curing of concrete walls and columns shall be done after checking that water will not damage the surface and before form removal.

(d) Soaker hoses shall be placed at the top of walls and columns so that water will enter between concrete and formwork.

(e) Alternate wetting and drying of the concrete surfaces shall not be permitted.

9.3.3.3 Fogging:

(a) Fogging equipment shall be set up to allow complete coverage of the area to be cured.

(b) The relative humidity above the slab shall be maintained at a level to prevent surface drying and the accumulation of standing water on the surface.

(c) Alternate wetting and drying of the concrete surfaces shall not be permitted.

9.3.3.4 Sheet material: Placement of the sheet material on the concrete surface shall be carried out as soon as it is possible without marring the surface as follows:

(a) All exposed concrete surfaces and beyond the edge of the concrete surface shall be covered by securely tape sheeting together or lap.

(b) The concrete shall be kept continuously wet under the sheeting.

(c) The integrity of the material to minimize evaporation loss throughout the curing period shall be maintained.

9.3.3.5 Liquid membrane-forming curing compounds:

(a) Liquid membrane-forming curing compounds shall be applied uniformly and at the rate specified in the contract or as recommended by the manufacturer.

(b) The application rate shall not less than specified in ASTM C309 or ASTM C1315 as tested using ASTM C156.

(c) Curing compounds shall be applied immediately after final finishing and as soon as bleeding has essentially ceased, as evidenced by the disappearance of free water and no visible water sheen.

(d) Adequate ventilation shall be provided during the application of the membrane-forming curing compounds.

(e) The membrane shall be protected from damage for the duration of the curing period.

9.3.3.6 Absorbent material:

(a) The absorbent material shall be nonstaining.

(b) Absorbent materials shall be distributed uniformly on the concrete surface after final finishing without marring the surface.

(c) Apply water to the materials, taking care not to displace them.

(d) Water shall be applied during the curing period as needed to keep the concrete surfaces continuously wet.

(e) Alternate wetting and drying of the concrete surfaces shall not be permitted.

9.3.4 Termination of curing

9.3.4.1 Concrete shall be cured for at least 7 days provided that the concrete surface temperature is at least 10°C if testing of strength specimens is not specified for termination of curing procedures. When the temperature is lower, refer to Section 9.3.7.

9.3.4.2 One of the following conditions shall be satisfied in case the termination of curing period is based on the development of strength:

(a) Concrete compressive strength of the cylinders field cured in accordance with ASTM C31M shall meet or exceed 70 percent of design concrete compressive strength required by the Concrete Documents.

(b) The compressive strength of laboratory-cured cylinders, representative of the in-place concrete, exceeds 85 percent f'_c, provided the temperature of the in-place concrete has been maintained at 10°C or higher during curing.

9.3.4.3 General testing requirements—Tests to determine time of termination for curing measures shall be performed by an approved testing agency acceptable to the Architect/Engineer.

(a) Testing of strength specimens: Cylinders shall be molded in accordance with ASTM C31/C31M and tested in accordance with ASTM C39/C39M in accordance with project requirements.

(b) Curing shall be maintained until tests of at least two 150 × 300 mm cylinders or at least three 100 × 200 mm cylinders, field-cured alongside the concrete they represent, have reached the compressive strength specified for termination of curing.

9.3.4.4 Unless otherwise specified, if one of the curing procedures in Section 9.3.3 is used initially, the curing procedure may be replaced by one of the other procedures in Section 9.3.3 after concrete is 1 day old, provided the surface of concrete does not become dry before replacement procedure is applied.

9.3.5 Protection from mechanical injury

9.3.5.1 Concrete shall be protected from damaging mechanical disturbances during the curing period.

9.3.5.2 Finished surfaces shall be protected from damage by construction equipment, materials or methods, application of curing procedures, or by running water.

9.3.6 Hot weather curing

9.3.6.1 Protection and additional curing requirements shall be implemented during hot weather.

9.3.6.2 Initial curing method or methods defined in Section 9.3.1 shall be used and in addition the requirements of Chapter 10 shall be met when evaporation rates are expected to be high.

9.3.6.3 Preparation for hot weather curing procedures shall be implemented before hot weather conditions occur.

9.3.6.4 Drying of the concrete shall be prevented before the application of the final curing methods, by using an appropriate initial-curing method.

9.3.6.5 Shade the formwork, reinforcing steel, and concrete from direct sunlight to prevent rapid water loss and drying of the concrete surface when necessary.

9.3.6.6 Use liquid applied evaporation retardants, fogging, wind screens, or shade (individually or in combination) to control the rate of bleed water evaporation and subsequent drying of the concrete.

9.3.6.7 When loss of moisture from the concrete cannot be controlled by the measures described in Section 9.3.6.6 , alternate curing procedures shall be implemented such as placing and finishing concrete at night or postponing or delaying placement until conditions are acceptable.

9.3.6.8 Final curing: Final curing methods shall be employed immediately upon completion of the final finishing operation.

9.3.7 Cold weather curing

9.3.7.1 Protection and additional curing requirements shall be implemented during cold weather.

9.3.7.2 Concrete shall be protected from the effects of cold weather throughout the process of placing, finishing, and curing the concrete.

9.3.7.3 Application of water shall not be initiated when freezing weather is to occur during the curing period.

9.3.7.4 Saturated concrete shall not be exposed to cycles of freezing and thawing until the concrete has reached the compressive strength of 24 MPa and the concrete surface shall be protected from

freezing temperatures for at least 3 days after termination of application of water to the surface.

9.3.7.5 Concrete temperature shall be maintained as required by Chapter 11 of this Code during the curing period.

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CHAPTER 10—HOT WEATHER CONCRETING

10.1—General

10.1.1 Scope

10.1.1.1 This Chapter covers requirements for hot weather concrete construction.

10.1.2 Definitions

10.1.2.1 Hot weather—one or a combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results:

(a) high ambient temperature
(b) high concrete temperature
(c) low relative humidity
(d) high wind speed.

10.1.2.2 Other terms used in this Chapter are as defined in Chapter 6.

10.1.3 Referenced standards

10.1.3.1 Standards cited in this Chapter are listed in Chapter 6 with their titles and serial designations.

10.1.4 Submittals by the Contractor

10.1.4.1 Concrete mixture proportions shall be submitted by the Contractor to the Architect/Engineer for review and approval.

10.1.4.2 Submittal shall include the constituent materials and proportions of the proposed concrete mixture, in addition to test results obtained from past field experience or preconstruction testing. Test results shall meet all the applicable requirements in the project specification.

10.1.4.3 Procedures for production, placement, finishing, curing, and protection of concrete during hot weather conditions shall be submitted by the Contractor to the Architect/Engineer for review and approval, before the preplacement meeting.

10.1.4.4 Submittals from the Contractor shall indicate the methods to be used for pre- and post-cooling of the concrete, and the order in which they will be initiated when multiple methods are proposed.

10.1.5 Preplacement meeting

10.1.5.1 A preplacement meeting shall be held at least 15 days prior to beginning concrete construction to review and approve hot weather concreting procedures and the anticipated effect on the proposed mixture proportions, as follows:

(a) A preplacement meeting agenda, including hot weather concreting procedures, shall be sent to representatives of concerned parties not less than 10 days before the scheduled date of the preplacement meeting.
(b) Preplacement meeting attendance shall include, but is not limited to, representatives of the contractor, concrete subcontractor (if different from main contractor), testing agency, engineer of record, and ready-mixed concrete producer.
(c) Minutes of preplacement meeting shall be distributed to representatives of relevant parties within 5 days after the preplacement meeting.

10.1.6 Quality assurance and quality control

10.1.6.1 Quality assurance and Quality control shall comply with the requirements of Chapter 6, Section 6.4.

10.2—Products

10.2.1 General

10.2.1.1 All materials and equipment required for curing and protection shall be procured and stored by the Contractor at or near the project site before hot weather concreting begins.

10.3—Execution

10.3.1 Evaporation control measures

10.3.1.1 All materials required for evaporation control measures shall be prepared and made available on site so that accepted measures are performed as necessary.

10.3.1.2 Accepted evaporation control measures shall provide adequate protection of, and prevent rapid evaporation from, the fresh concrete surface.

10.3.1.3 Control measures shall remain in place while the concrete and air temperatures, relative humidity of the air, and the wind speed have the capacity to evaporate free water from the fresh

concrete surface at a rate that is equal to or greater than 1.0 kg/m^2/h, unless otherwise accepted.

10.3.1.4 Evaporation rate of surface water shall be estimated using Uno Equation (Eq. (10-1)):

$$E = 5[(T_c + 18)2.5 - r\,(T_a + 18)2.5]\,(V + 4) \times 10^{-6} \quad \textbf{(10-1)}$$

where, E = mass of water evaporated in kg per m^2 of water covered surface per hour; T_c = temperature of the evaporating surface taken as the concrete temperature in °C; r = relative humidity of air surrounding the concrete; expressed as percentage of relative humidity of air divided by 100 (air relative humidity is measured at a level approximately 1.2 to 1.8 m above the evaporating surface on the windward side and shielded from the sun's rays); T_a = temperature of the air surrounding the concrete in °C (air temperature is measured at a level approximately 1.2 to 1.8 m above the evaporating surface on the windward side and shielded from the sun's rays); and V = average wind speed in km/h, measured at 0.5 m above the evaporating surface.

10.3.1.5 Site conditions, including air temperature, relative humidity, and wind speed, shall be monitored to assess the need for evaporation control measures beginning no later than 1 hour before beginning concrete placing operations. Continue to monitor site conditions at intervals of 30 minutes or less until accepted curing procedures have been applied.

10.3.1.6 For calculating the rate of evaporation of surface water, equipment or instruments used shall be certified by the manufacturer as accurate to within 1°C, 5 percent relative humidity, and 1.6 km/h wind speed. Equipment shall be used in accordance with the product manufacturer recommendations.

10.3.2 Slump and maximum temperature of fresh concrete at time of discharge

10.3.2.1 Fresh concrete shall be tested for slump and concrete temperature at time of discharge for each delivery truck.

10.3.2.2 The temperature of fresh concrete shall be as specified in the contract but shall not exceed 35°C at the time of discharge.

10.3.2.3 Slump of fresh concrete at time of discharge shall meet the specified limits in the contract.

10.3.2.4 Temperature and slump of fresh concrete shall be measured in accordance with ASTM C1064/ C1064M and ASTM C143/C143M, respectively.

10.3.2.5 Computer modeling to predict fresh concrete temperature shall not be used as a substitute for preconstruction testing. Computer modeling is permitted only to assist in determining additional control measures for protecting the concrete surface from highly evaporative ambient conditions.

10.3.3 Qualification of concrete mixture

10.3.3.1 Laboratory trial batch: The laboratory concrete trial mixture shall be batched within 2°C of the proposed maximum fresh concrete temperature in a drum or pan-type concrete mixer and mixed in accordance with modified ASTM C192/C192M.

10.3.3.2 The proposed concrete mixture shall meet the specified slump range at the end of the laboratory mixing period and shall meet the required strength at the specified test age.

10.3.3.3 Field trial batch: The field concrete trial mixture shall be batched within 2°C of the proposed maximum concrete temperature of 35°C in a truck-mixer with a minimum batch size of 3 m^3. The trial mixture shall be conducted as follows:

(a) The concrete mixture shall be held in the mixer for 120 minutes, unless otherwise accepted.
(b) During the entire 120-minute period, the mixer shall be agitated at 1 to 6 rpm.
(c) At the end of 120 minutes, the concrete mixture shall be mixed for 2 minutes at mixing speed.
(d) The addition of water, chemical admixture, or both, to adjust slump is permitted during mixing and agitation periods of the field trial batch, but the specified concrete mixture w/cm shall not be exceeded.
(e) The slump of the concrete mixture during the middle third of the 120-minute mixing period shall be checked and adjusted as needed.
(f) The proposed concrete mixture shall be within the specified slump range at the end of the 120-minute field mixing period and shall meet the required strength at the specified test age in accordance with standard curing practices in ASTM C31/C31M.

10.3.3.4 Testing requirements-The following tests shall be performed and results obtained in accordance with the listed ASTM standards:

(a) Slump—ASTM C143/C143M
(b) Air content—ASTM C231/C231M or C173/C173M
(c) Concrete temperature—ASTM C1064/C1064M
(d) Density (unit weight)—ASTM C138/C138M
(e) Compressive strength—ASTM C39/C39M
(f) Flexural strength (if specified)—ASTM C78/C78M or C293/C293M

10.3.3.5 Slump and concrete and air temperature measurements shall be performed after initial mixing, intermediately as needed or as desired, and at the conclusion of the mixing period, along with density measurement and fabrication of strength test specimens.

10.3.3.6 Air content shall be performed after initial mixing.

10.3.4 Concrete production and delivery

10.3.4.1 Concrete shall be produced at a temperature such that its maximum temperature at discharge shall not exceed the accepted maximum concrete temperature.

10.3.4.2 Acceptable production methods to reduce the concrete temperature shall be implemented. Acceptable production methods to reduce the concrete temperature include, but are not limited to, shading aggregate stockpiles, sprinkling water on coarse aggregate stockpiles, using chilled water for concrete production and substituting chipped or shaved iced for portions of the mixing water.

10.3.4.3 Substitution of other cooling methods shall be considered by the Architect/Engineer upon written request before concrete placement and accompanied by supporting data.

10.3.4.4 Concrete shall be delivered in accordance with ASTM C94/C94M.

10.3.4.5 Discharge of the concrete shall be completed within 120 minutes after the introduction of the mixing water to the cement and aggregates.

10.3.5 Concrete placement and finishing

10.3.5.1 Concrete temperature as placed shall meet the specified requirements.

10.3.5.2 If temperature of reinforcement, embedments, or forms is greater than 50°C, use a fine mist of water to moisten and cool hot surfaces. Standing water shall be removed before placing concrete.

10.3.5.3 Concrete placement and finishing operations shall proceed as quickly as conditions allow.

10.3.5.4 Retempering of concrete by the addition of water to compensate for the loss of workability shall not be allowed.

10.3.5.5 All necessary precautions shall be taken to prevent plastic shrinkage cracking. In particular, precautions shall be taken during placing of concrete to avoid excessive evaporation of mix water.

10.3.6 Concrete bleed-water evaporation

10.3.6.1 Concrete surface bleed-water evaporation shall be controlled by using materials and methods in accordance with Chapter 9 of this code.

10.3.7 Concrete curing

10.3.7.1 Concrete shall be cured in accordance with Chapter 9 of this code.

10.3.7.2 Moist curing for the entire curing period is recommended. However, if moist curing cannot be continued beyond three days, concrete shall be protected from drying with heat-reflecting plastic sheets, membrane-forming curing compounds or curing paper.

10.3.8 Concrete protection

10.3.8.1 Concrete surface shall be protected from decreases in concrete temperature greater than 22°C during the 24-hour period following placement.

10.3.8.2 Acceptable protection methods for preventing excessive temperature decrease shall be implemented.

10.3.8.3 Timing the removal of these protective measures is critical and shall be implemented in such a way as to avoid thermal shrinkage cracks caused by a rapid decrease in concrete surface temperature upon protection removal.

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CHAPTER 11—COLD WEATHER CONCRETING

11.1—General

11.1.1 Scope

11.1.1.1 This Chapter covers requirements for cold weather concreting and protection of concrete from freezing during the specified protection period.

11.1.2 Definitions

11.1.2.1 Definition of terms specific to this Chapter:

Cold weather—A period when for more than three successive days the average daily outdoor temperature drops below 4ºC. The average daily temperature is the average of the highest and lowest temperature during the period from midnight to midnight. When temperatures above 10ºC occur during more than half of any 24 hr duration, the period shall no longer be regarded as cold weather.

Protection period—The required time during which the concrete is maintained at or above a specific temperature in order to prevent freezing of the concrete or to ensure the necessary strength development for structural safety. Other terms used in this Chapter are as defined in Chapter 6.

11.1.3 Referenced standards

11.1.3.1 Standards cited in this Chapter are listed in Chapter 6 with their titles and serial designations.

11.1.4 Submittals by the Contractor

11.1.4.1 Concrete mixture proportions shall be submitted by the Contractor to the Architect/Engineer for review and approval.

11.1.4.2 Submittal shall include the constituent materials and proportions of the proposed concrete mixture, in addition to test results obtained from past field experience or preconstruction testing. Test results shall meet all the applicable requirements in the project specification.

11.1.4.3 Contractor shall submit detailed procedures for production, transportation, placement, protection, finishing, curing, and temperature monitoring of concrete during cold weather to the Architect/Engineer for review and approval.

11.1.4.4 Submittals from the Contractor shall include procedures to be implemented upon abrupt changes in weather conditions or equipment failures. Cold weather concreting shall not be allowed until these procedures have been reviewed and accepted.

11.1.5 Quality assurance and quality control

11.1.5.1 Quality assurance and Quality control shall comply with the requirements of Section 6.4 in Chapter 6.

11.2—Materials

11.2.1 Protection and curing.

11.2.1.1 All materials and equipment required for protection and curing shall be procured and stored by the Contractor at or near the project site before cold weather concreting.

11.3—Execution

11.3.1 Preparation before concreting

11.3.1.1 All snow, ice, and frost, if present, shall be removed from the surfaces, including reinforcement, against which the concrete is to be placed.

11.3.1.2 Concrete around massive embedments identified in the Contract Documents shall not be placed unless such embedments are at a temperature above freezing.

11.3.2 Concrete temperature

11.3.2.1 Placement temperature

(a) The minimum temperature of concrete immediately after placement depends on the least dimension of section. It shall remain within 13ºC to 5ºC for least section dimension less than 300 mm and more than 1800 mm, respectively.

(b) The temperature of concrete as placed shall not exceed the values given in section 11.3.2.1 (a) by more than 11ºC.

11.3.2.2 Protection temperature

(a) Unless otherwise specified, the minimum temperature of concrete during the protection period shall be as given in 11.3.2.1 (a).
(b) Temperatures specified to be maintained during the protection period shall be those measured at the concrete surface, at regular time intervals as specified in the Contract Documents, whether the surface is in contact with formwork, insulation, or air.

11.3.2.3 Termination of protection

(a) The maximum decrease in temperature measured at the surface of the concrete in a 24-hour period shall not exceed 28ºC for least dimension of section less than 300 mm and 11ºC for least dimension of section more than 1800 mm.
(b) Protection shall be maintained until the surface temperature of the concrete is within 11ºC of the ambient or surrounding temperatures.
(c) When the surface temperature of the concrete is within 11ºC of the ambient or surrounding temperature, all protection may be removed.

11.3.3 Curing of concrete

11.3.3.1 Concrete shall be cured in accordance with Chapter 9 of this code.

11.3.3.2 Concrete shall be prevented from drying during the required curing period.

11.3.3.3 Water curing, if used, shall be terminated at least 24 hr before any anticipated exposure of the concrete to freezing temperatures.

11.3.4 Protection of concrete

11.3.4.1 Protection against freezing

(a) Concrete shall be cured and protected against damage from freezing for a minimum period of 3 days, unless otherwise specified.
(b) The surface temperature of the concrete shall be maintained during that period in accordance with Section 11.3.2.2 , unless otherwise specified.

11.3.4.2 Concrete surfaces shall be protected against freezing for the first 24 hr after placing during periods not defined as cold weather, but when freezing temperatures may occur.

11.3.4.3 Protection for structural safety

(a) The duration of the protection period shall be extended in cold, if required for structural safety, to ensure the necessary strength development.
(b) The strength required for formwork removal, for reshoring, or for continued construction shall be as specified in the Contract Documents for each type of structural member.
(c) The attainment of the required strength shall be verified by using ASTM C 31/C31M and tested in accordance with ASTM C 39/C39M.

11.3.4.4 Protection deficiency

(a) The specified protection period shall be extended in case of protection deficiency if the temperature requirements during the specified protection period are not met but the concrete was prevented from freezing.
(b) The protection duration shall be continued until twice the deficiency of protection in degree-hours is made up.

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PART III—INSPECTION AND TESTING AGENCIES

CHAPTER 12—GENERAL

12.1—Scope

12.1.1 This Part of the Code (Chapter 12 through Chapter 14) defines the minimum requirements for agencies engaged in any of the following:

(a) Inspection of specified methods and materials used in construction,
(b) Special Inspection, and
(c) Testing of materials used in construction.

12.1.2 Criteria are provided for assessing the competence of an agency to properly perform designated inspections, tests, or Special Inspection services. This part of the Code establishes essential characteristics pertaining to the organization, management, personnel, facilities, quality systems, responsibilities, duties, inspection and testing methods, records, and reports of the agency. These requirements may be supplemented by more specific criteria and requirements, if required.

12.1.3 This code requirement shall be used as a basis to assess an agency and is intended for use in accrediting agencies, public or private, engaged in inspection, testing, and Special Inspection of construction activities and materials used in construction. These services include but are not limited to reinforced concrete, precast concrete, structural steel erection, welding, bolting, soil and rock, foundations, masonry, sprayed fire resistive materials, fire stops, exterior insulation and finish system (EIFS), and Special Cases.

12.1.4 A certificate of accreditation, including the scope of accreditation, is required to comply with this code. The certificate of accreditation shall identify the agency and its location along with the accreditation body, the accreditation standard, the general field (s) of inspection or testing, effective dates, conditions and authorized signatures, seals, or combinations thereof, of the accreditation body. The certificate must be accompanied by an accreditation scope to fully describe the technical competence of the agency.

12.1.5 The users of an accredited agency must review the agency's scope of accreditation to ensure the agency has been accredited for its technical competence to perform the specific inspections or tests requested by the user.

12.1.6 The requirements of this Code are not intended to:

(a) Circumvent or replace the agreement between the agency and the owner that shall clearly define the responsibilities and authorities of the agency;
(b) Address design requirements that supersede applicable codes, laws, and regulations; or
(c) Address construction means, methods, techniques, or sequences.

12.2—Definitions

12.2.1 Definitions of terms specific to this Part of the Code are given below:

Accreditation—the third-party attestation of an agency's competence to perform inspection, or testing services, or both.

Accreditation body—the body that administers the accreditation program and issues the certificate of accreditation.

Accreditation scope—the formal statement issued by the accreditation body to the agency that describes the specific inspections, tests, or both, for which the agency has demonstrated a competency in performing and is accredited.

Agency—the organization, or part thereof, authorized by the client or client's duly authorized representative to inspect, test, or both, construction activities and materials used in construction as required by the approved project plans and specifications.

Client— the party that contracts with the agency to perform its services.

Contractual agreement—the legally-binding service contract between the agency and the agency's client. The contractual agreement referred to throughout this Chapter may include testing, inspection, or Special Inspection services contracts.

Facility, main—a structure with a permanent address, which provides testing or inspection services, or both, for multiple projects for a period expected to be greater than three years.

Facility, permanent—as used to describe testing or inspection facilities, or both, expected to function for a period exceeding three years.

Facility, site—a structure, or a mobile, fully equipped, self-contained unit, capable of conducting specific tests or inspections or both, established in a dedicated area on-site for the duration of a specific project, but not for projects expected to exceed three years.

Facility, sub—a structure with a permanent address, that is physically separate from, but considered an extension of the main facility, which generally provides testing or inspection services or both for multiple projects.

Facility, temporary—as used to describe testing or inspection facilities or both, expected to function for a period not to exceed three years.

Inspection—a technical procedure based on visual observation or field measurement of construction activities or materials used in construction employed to evaluate activities or materials and determine general compliance with approved project plans and specifications.

Inspection agency—an agency that uses technical procedures and individuals with special expertise to perform inspection activities. The inspection agency and testing agency may be one organization or separate organizations.

Inspector/technician—a person employed by the agency assigned to perform the inspection or testing of construction activities or materials used in construction or both.

Masonry—as used in construction (load bearing or non-load bearing), masonry units, brick, mortar and grout.

Nondestructive testing—procedures for testing construction activities or materials used in construction, or both, that does not impair the serviceability of the materials or assemblies under test.

Professional Engineer—an individual who is registered or licensed to engage in the practice of engineering as defined by the statutory requirements of the professional registration or licensing laws of Saudi Arabia.

Registered design professional—an individual who is registered or licensed to practice their respective design profession as defined by the statutory requirements of the professional registration laws of Saudi Arabia.

Special Inspection—the unique term applied to the process of inspection or monitoring of specific materials, equipment, installation, fabrication, erection or placement of components and connections by individuals with special expertise as approved by the applicable building official to ensure compliance with the approved project plans and specifications.

Special Inspection agency—an accredited third-party inspection agency approved by the applicable building official to perform Special Inspections.

Special Inspector—a person employed by a Special Inspection agency and approved by the applicable building official, certified by a third party to perform certain types of inspection as required by the applicable building code.

Steel—structural steel plates and shapes used wholly or in part for structures including reinforcing steel used in concrete. It is not intended to include steels used in conjunction with mechanical, electrical, heating or air-conditioning equipment except for the supporting structures.

Testing—technical procedure performed on construction activities or materials used in construction with specified equipment that produces data unique to the construction activities or materials; the data are used to evaluate or determine selected properties or characteristics of the activities or

Testing agency—an agency that uses technical procedures, individuals with special expertise, and specified equipment to measure, sample, examine, test, or otherwise produce data unique to the construction activities or materials used in construction. The inspection agency and testing agency may be one or separate organizations. materials.

12.3—Referenced documents

12.3.1 ASTM International

C1077 Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

C1093 Practice for Accreditation of Testing Agencies for Masonry

D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

E4 Practices for Force Verification of Testing Machines

E543 Specification for Agencies Performing Nondestructive Testing

E605 Test Methods for Thickness and Density of Sprayed Fire-Resistive Material (SFRM) Applied to Structural Members

E736 Test Method for Cohesion/Adhesion of Sprayed Fire Resistive Materials Applied to Structural Members

E1513 Practice for Application of Sprayed Fire-Resistive Materials (SFRMs)

E2174 Practice for On-Site Inspection of Installed Firestops

E2393 Practice for On-Site Inspection of Installed Fire Resistive Joint Systems and Perimeter Fire Barriers

12.3.2 ISO Standards

17011 General Requirements for Accreditation Bodies Accrediting Conformity Assessment Bodies

17020 General Criteria for the Operation of Various Types of Bodies Performing Inspection

17025 General Requirements for the Competence of Calibration and Testing Laboratories.

12.3.3 American Welding Society (AWS) Documents

B1.11 Guide for the Visual Inspection of Welds

D1.1 Structural Welding Code, Steel

D1.4 Structural Welding Code—Reinforcing

D1.5 Bridge Welding Code

12.4—Impartiality and independence

12.4.1 Inspection and testing activities shall be undertaken impartially.

12.4.2 The agency shall be responsible for the impartiality of its inspection/ testing activities and shall not allow commercial, financial or other pressures to compromise impartiality.

12.4.3 The agency shall identify risks to its impartiality on an ongoing basis. This shall include those risks that arise from its activities, or from its relationships, or from the relationships of its personnel. A relationship that threatens the impartiality of the agency can be based on ownership, governance, management, personnel, shared resources, finances, contracts, marketing (including branding), and payment of a sales commission or other inducement for the referral of new clients, etc.

12.4.4 If a risk to impartiality is identified, the agency shall be able to demonstrate how it eliminates or minimizes such risk.

12.4.5 The agency shall have top management commitment to impartiality.

12.4.6 The agency performing third party inspection shall be independent and shall meet the type A requirements of Clause A.1 in SASO/ISO 17020.

12.5—Confidentiality

12.5.1 The agency shall be responsible, through legally enforceable commitments (for example, contractual agreements), for the management of all information obtained or created during the performance of inspection/testing activities. The agency shall inform the client, in advance, of the information it intends to place in the public domain. Except for information that the client makes publicly available, or when agreed between the agency and the client (e.g. for the purpose of responding to complaints), all other information is considered proprietary information and shall be regarded as confidential.

12.5.2 When the agency is required by law or authorized by contractual commitments to release confidential information, the client or individual concerned shall, unless prohibited by law, be notified of the information provided.

12.5.3 Information about the client obtained from sources other than the client (e.g. complainant, regulators) shall be treated as confidential.

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CHAPTER 13—QUALITY SYSTEM AND TECHNICAL REQUIREMENTS

13.1—Scope

13.1.1 This chapter covers key factors relevant to an agency's ability to produce precise, accurate test data or determine the conformity of construction activities and materials used in construction with regulations, codes, standards, and approved project plans and specifications containing the requirements against which the inspection or test, or both, will be performed. Specific or general requirements include:

(a) Facilities and management of the agency,
(b) Sufficiency and technical competency of personnel,
(c) Suitability, calibration, and maintenance of equipment,
(d) Quality system, audit, and review,
(e) Responsibilities, duties, and authority of agencies,
(f) Validity and appropriateness of sampling, testing, and inspection methods and procedures,
(g) Management of records,
(h) Reporting, review, and transmission of test and inspection data or findings, and

13.2—Organization and management

13.2.1 The agency shall be legally identifiable. It shall be organized and shall operate in such a way that its facilities meet the requirements of this Chapter.

13.2.1.1 Main facilities, sub-facilities, and permanent site facilities shall maintain personnel, equipment, procedures, and documentation as required in this Chapter. The manager for the main facility may also be responsible for a sub-facility or permanent site facility (see Sections 13.3.2.2 and 13.3.3.2). Main facilities, sub-facilities, and permanent site facilities shall be accredited in accordance with Section 13.6.4.1 to perform the functions described in this Code.

13.2.1.2 Temporary site facilities offering a defined scope of services for a specific project, which are demonstrably under the main facility's or sub-facility's technical direction and quality program, do not require separate accreditation. Agencies that use temporary site facilities for their projects shall describe the operation of these facilities in their quality manual.

13.2.1.3 An endorsement for the operation of temporary site facilities shall also be listed on the agency's accreditation certificate.

13.2.2 The agency shall:

13.2.2.1 Have managerial personnel with the authority and resources needed to discharge their duties.

13.2.2.2 Have arrangements to ensure that its personnel are free from any commercial, financial, and other pressures including trade organization rules that might adversely affect their independence, their judgment, and the integrity of their services. A Special Inspection agency or its personnel shall not be directly involved in the manufacture, supply, installation, use, or maintenance of the inspected items.

13.2.2.3 Be organized in such a way that confidence in its independence of judgment and integrity is maintained at all times.

13.2.2.4 Specify and document the responsibility, authority, qualifications, and interrelation of all personnel who manage, perform, or verify services affecting the quality of inspections or tests, or both.

13.2.2.5 Provide supervision by persons qualified to perform the inspections and tests and to implement relevant procedures. They shall be qualified to evaluate the objective of the inspections or tests and the results. The ratio of supervisory to non-supervisory personnel shall be such as to ensure adequate supervision.

13.2.2.6 Have a technical manager (however named) who has overall responsibility for the technical operations.

13.2.2.7 Have a quality manager (however named) who has the responsibility for the quality system and its implementation. The quality manager shall have direct access to the highest level of management at which decisions are made on agency policy or resources, and to the technical manager. In some agencies, the quality manager

may also be the technical manager or deputy technical manager.

13.2.2.8 Nominate deputies in case of absence of the technical or quality manager.

13.2.2.9 Where relevant, have documented policy and procedures to ensure the protection of clients' confidential information and proprietary rights.

13.2.2.10 Where appropriate, as determined by the agency's quality manual, participate in interlaboratory comparisons and proficiency testing programs.

13.3—Personnel

13.3.1 General

13.3.1.1 The agency shall have sufficient personnel having the necessary education, training, technical knowledge, certification as appropriate, and experience for their assigned functions.

13.3.1.2 The agency shall ensure that the training of its personnel is kept up-to-date.

13.3.1.3 Records of relevant certification, qualifications, training, skills, and experience of the technical personnel shall be maintained by the agency.

13.3.2 Construction Inspection and Testing Agency:

13.3.2.1 The following personnel requirements must be satisfied by the agency when inspection or testing services, or both, are being provided:

13.3.2.2 The inspection and testing services of the agency that provides the quality control or quality assurance program, or both, as related to construction activities or materials used in construction, shall be under the direction of a person charged with engineering managerial responsibility. The person shall be a professional engineer and a full-time employee of that agency. The person shall have at least five years experience in inspection and testing of construction activities and materials used in construction. The organization may consist of one or more separate facilities providing inspection or testing services or both. A professional engineer may have engineering managerial responsibility for one or more facilities within the organization.

13.3.2.3 When a producer's or manufacturer's laboratory only serves as a quality control laboratory and does not produce tests for acceptance, payment, or the official record, the requirement for a professional engineer is waived. However, the laboratory function of the organization shall be supervised by a quality control manager. The quality control manager shall have at least five years experience in testing of that particular construction material, and be a full time employee of the organization. The quality control manager will have the authority to make changes in production to ensure that quality material is produced. He may serve as the quality control manager for several materials production facilities. The quality control manager shall have the certifications appropriate to the testing of the materials supervised.

13.3.2.4 A laboratory supervisor shall have at least three years experience performing tests in relevant construction activities and materials used in construction. This person shall be able to demonstrate either by oral or written examination, or both, their ability to perform the tests normally required in the manner stipulated under ASTM or other governing test procedures and shall be capable of evaluating the test results in terms of specification compliance. Certification by qualified national or international authorities as appropriate to the services is required.

13.3.2.5 A field supervisor shall have at least three years inspection experience in the type of services being supervised. This person shall be able to demonstrate, either by oral or written examination, or both, their ability to perform correctly the required duties and shall be capable of evaluating the inspection or test results in terms of specification compliance. Certification by qualified national or international authorities as appropriate to the services is required.

13.3.2.6 Inspector or Technician—This person shall have sufficient education and on-the-job training or trade school training to properly perform the inspection or test to which the person is assigned. This person must be able to demonstrate competence for the test or inspection that is being conducted either by oral or written examination, or both. Certification as appropriate for the services being performed, or certification by other qualified national authorities as appropriate to the service, shall be considered as one means of documenting competency. The inspector or technician shall work under the direct supervision of personnel meeting the requirements of Sections 13.3.2.4 or 13.3.2.5 .

13.3.2.7 It is satisfactory for a person to fill one or more of the levels of management, supervision, inspector, or technician positions in accordance with Sections 13.3.2.2 , 13.3.2.3 , 13.3.2.4 , and

13.3.2.5 , provided the person qualifies for the highest level worked. It is also recognized that frequently some tests and inspections are conducted at small field or peripheral locations; it is not the intent of this code that the supervisory personnel be directly present at such locations at all times. If the qualified person in Section 13.3.2.2 performs as a supervisor, they do not have to comply with the certification requirements.

13.3.3 Special Inspection Agency:

13.3.3.1 The following personnel requirements must be satisfied by an agency that provides Special Inspection services:

13.3.3.2 The Special Inspection services of the agency shall be under the direction of a registered design professional and a full-time employee of that agency. The person shall have at least two years experience in Special Inspections. The organization can consist of one or more separate facilities providing Special Inspection. A registered design professional can have managerial responsibility for one or more facilities within the organization as defined by Section 13.2.

13.3.3.3 The field supervisor of Special Inspection shall have at least two years Special Inspection experience in the type of work being supervised. This person shall be certified in the areas he is supervising.

13.3.3.4 The Special Inspector shall be certified by a third party. This certification exam shall include; a written examination that shall include; reading plans as a performance element. The examination shall demonstrate the candidate's ability to correctly perform the required duties and evaluate the inspection results for specification and code compliance.

13.3.3.5 The registered design professional according to Section 13.3.3.2 , in addition to the requirements of Section 13.3.3.4 shall document the experience and job training of each Special Inspector being supervised. The Special Inspection agency shall maintain such documentation for a minimum of three years after the individual(s) have left their employment.

13.3.3.6 A person can fill one or more of the levels of management, supervision, inspector, or technician positions in accordance with Sections 13.3.3.2 , 13.3.3.3 and 13.3.3.4 , provided the person qualifies for the highest level worked.

13.4—Equipment

13.4.1 The agency shall furnish all items of equipment, including reference materials, required for the correct performance of inspections and tests. In those cases, where the agency needs to use equipment outside its permanent control, it shall ensure that the relevant requirements of this specification are met.

13.4.2 All equipment shall be properly maintained. Maintenance procedures shall be documented and shall include a schedule for future maintenance.

13.4.2.1 Any equipment that has been subjected to overloading or mishandling, or that gives suspect results, or has been shown by verification or otherwise to be defective, shall be taken out of service, clearly identified, and wherever possible, stored at a specified place until it has been repaired and shown by calibration, verification, or test to perform satisfactorily.

(a) The agency shall examine the effect of this defect on previous inspections or tests.

13.4.3 Each item of equipment including reference materials shall, when appropriate, be labeled, marked or otherwise identified to indicate its calibration status.

13.4.4 Records shall be maintained for each item of equipment and all reference materials significant to the inspections or tests performed. The records shall include:

(a) The name of the item of equipment,
(b) The manufacturer's name, type identification, and serial number or other unique identification,
(c) Date received and date placed in service,
(d) Condition when received (for example, new, used, reconditioned, and so forth),
(e) Copy of the manufacturer's instructions, where available, condition when received (for example, new, used, reconditioned, and so forth),
(f) Details of maintenance carried out to date,
(g) Dates and results of calibrations or verifications, or both, and date of next calibration or verification, or both,
(h) History of any damage, malfunction, or repair, and
(i) Current location.

13.5—Quality System, audit and review

13.5.1 The agency shall establish and maintain a quality system appropriate to the type, range, and volume of inspections and testing activities it undertakes. The elements of this system shall be documented. The quality documentation shall be available for use by the agency's personnel.

13.5.1.1 The agency shall define and document its policies and objectives for, and its commitment to good practice and quality of, inspection or testing services.

13.5.1.2 The agency management shall ensure that these policies and objectives are documented in a quality manual and communicated to, and understood and implemented by, all personnel concerned. The quality manual shall be maintained current under the responsibility of the quality manager.

13.5.2 The quality manual and related quality documentation shall state the agency's policies and operational procedures established in order to meet the requirements of this specification. The quality manual and related quality documentation shall also contain:

13.5.2.1 A quality policy statement, including objectives and commitments, by top management;

13.5.2.2 The organization and management structure of the agency, its place in any parent organization and relevant organizational charts;

13.5.2.3 The relations between management, technical operations, support services, and the quality system;

13.5.2.4 Procedures for control and maintenance of documentation;

13.5.2.5 Job descriptions of key personnel and reference to the job descriptions of other personnel;

13.5.2.6 Identification of the agency's approved signatories (where this concept is appropriate);

13.5.2.7 The agency's procedures for achieving traceability of measurements;

13.5.2.8 The agency's scope of inspections or tests, or both;

13.5.2.9 Arrangements for the agency to review all new services to ensure that it has the appropriate facilities and resources before commencing such services;

13.5.2.10 Reference to the test procedures used;

13.5.2.11 Procedures for handling inspection and test items;

13.5.2.12 Reference to the equipment and reference measurement standards used;

13.5.2.13 Reference to procedures for calibration, verification and maintenance of equipment;

13.5.2.14 Procedures to be followed for feedback and corrective action whenever testing discrepancies are detected, or departures from documented policies and procedures occur;

13.5.2.15 The agency's arrangements for permitting departures from documented policies, procedures, or standards;

13.5.2.16 Procedures for dealing with complaints;

13.5.2.17 Procedures for protecting confidentiality and proprietary rights; and

13.5.2.18 Procedures for audit and review.

13.5.3 The agency shall arrange for audits or inspections of its activities at appropriate intervals to verify that its operations continue to comply with the requirements of the quality system. Such audits shall be carried out by qualified personnel who are independent of the activity to be audited.

13.5.3.1 If the audit findings cast doubt on the correctness or validity of the agency's inspections or test results, the agency shall investigate the findings and circumstances to determine if the agency's inspection or test results reported to the client and other parties were affected. If the agency's investigation determines that the agency's inspection or test results were affected, the agency shall take immediate corrective action and shall immediately notify, in writing, the client and any other party as required by the contractual agreement.

13.5.4 The quality system adopted to satisfy the requirements of this specification shall be reviewed at least once a year by the management to ensure its continuing suitability and effectiveness and to introduce any necessary changes or improvements.

13.5.5 All audit and review findings, external and internal, and any corrective actions that arise from them shall be documented. The person responsible for quality shall ensure that these actions are discharged within the agreed timescale.

13.5.6 In addition to periodic audits, the agency shall ensure the quality of results provided to clients by implementing checks. These checks shall be

reviewed and shall include, as appropriate, but are not limited to:

13.5.6.1 Internal quality control schemes using, whenever possible, statistical techniques,

13.5.6.2 Participation in proficiency testing or peer reviews,

13.5.6.3 Regular use of certified reference materials or in house quality control using secondary reference materials, or both,

13.5.6.4 Replicate inspections or testing using the same or different methods,

13.5.6.5 Re-inspection or re-testing of retained items, and

13.5.6.6 Correlation of results for different characteristics of an item.

13.5.7 Compliance with the requirements specified in SASO/ISO/IEC 17025 for laboratories and SASO/ISO/IEC 17020 for inspection bodies would satisfy the requirements of Sections 13.5, 13.6, 13.7, 13.8, and 13.9 of this Chapter.

13.6—Responsibilities and duties

13.6.1 It shall be the responsibility of the agency to ensure that it performs only inspections or tests for which it is adequately equipped and staffed, and that its personnel perform only inspections or tests for which they are adequately trained.

13.6.2 The following duties are those usually performed by the agency:

13.6.2.1 Obtain representative samples of those materials required by the approved project plans and specifications, and authorized by the contractual agreement to be tested and evaluated.

13.6.2.2 When samples are collected by the agency, the agency must ensure that there is proper protection, handling, and storing of the samples to ensure that they remain representative of the material being used at the time of sampling.

13.6.2.3 When the agency is responsible for collecting samples, the samples must be identified with the respective portions of the work in which the material represented was or will be used.

13.6.2.4 Perform all testing and inspection operations in accordance with appropriate standards as referenced in the contractual agreement.

13.6.2.5 Call to the attention of the client any irregularities or deficiencies in the construction materials or processes, or both, as related to construction materials, that the contractual agreement specifically states the agency is responsible for testing or inspecting.

13.6.2.6 Submit promptly to the client and distribute as specified in the contractual agreement formal reports of all tests and inspections which indicate compliance or noncompliance with the approved project plans and specifications. The reports shall be complete and factual, citing the methods used in obtaining samples, the tests performed, the specified values for the measured characteristics, the values obtained, the parts of the structure involved, and similar pertinent data. The agency shall be prepared to substantiate its reports to the extent necessary.

13.6.3 Unless specifically authorized, the agency does not have the right of rejection.

13.6.4 The agency shall have its laboratory procedures and equipment inspected at intervals of not more than three years by a qualified national authority as evidence of its competence to perform the required tests.

13.6.4.1 The agency shall demonstrate evidence of meeting the requirements of this Code through official accreditation in the field of its operations.

13.6.5 The agency shall supply the qualified accreditation authority with the qualification of its Personnel as listed in Section 13.3. At a minimum each person shall be re-evaluated internally or externally, at least every three years for each test or inspection or both the person is authorized to perform.

13.7—Inspections and test methods

13.7.1 The agency shall have documented instructions on the use and operations of all relevant equipment, on the handling and preparation of items, and for inspection, calibration, or testing, or a combination thereof, where the absence of such instructions could jeopardize the inspections or tests. All instruction, standards, manuals and reference data relevant to the services of the agency shall be maintained up-to-date and be readily available to the personnel and external auditors.

13.7.2 The agency shall use appropriate test methods and procedures for all inspections and tests and related activities within its responsibility (including sampling, handling, transport and storage, and preparation of items, estimation of uncertainty of measurement, and analysis of inspection data or test data, or both). They shall be consistent with the accuracy required, and with any

standard specifications relevant to the inspections, or tests concerned.

13.7.3 Where it is necessary to employ test methods that have not been established as standards, these shall be subject to agreement with the client, be fully documented and validated, and be available to the client and other recipients of the relevant reports.

13.7.4 Where sampling is carried out as part of the test method, the agency shall use documented procedures and appropriate statistical techniques to select samples.

13.7.5 Calculations and data transfers shall be subject to appropriate checks.

13.7.6 Where computers or automated equipment are used for the capture, processing, manipulation, recording, reporting, storage, or retrieval of inspection or test data, the agency shall ensure that:

13.7.6.1 All requirements of this specification are complied with,

13.7.6.2 Computer software is documented and adequate for use,

13.7.6.3 Procedures are established and implemented for protecting the integrity of data; such procedures shall include, but are not limited to: the integrity of data entry or capture, data storage, data transmission and data processing,

13.7.6.4 Computer and automated equipment is maintained to ensure proper functioning and provided with the environmental and operating conditions necessary to maintain the integrity of inspection and test data, and

13.7.6.5 Appropriate procedures for the maintenance of security of data including the prevention of unauthorized access to, and unauthorized amendment of, computer records are established and implemented.

13.7.7 Documented procedures shall exist for the purchase, reception and storage of consumable materials used for the technical operations of the agency.

13.8—Records

13.8.1 The agency shall establish and maintain a documented system to identify, collect, index, access, file, store, maintain, and dispose of management and technical records to suit its particular circumstances and to comply with applicable regulations.

13.8.2 A record retention period shall be established but shall be no less than 3 years.

13.8.3 Records shall be legible and include sufficient information to permit satisfactory recapitulation of the inspection.

13.8.4 Records shall be safely stored and retained to prevent damage, deterioration or loss.

13.8.5 Records shall be held secure and in confidence to the client, unless otherwise authorized by the client or required by law, regulation, or valid court order.

13.9—Report

13.9.1 The services performed by the agency shall be documented by a retrievable report that accurately, clearly, objectively, and unambiguously presents measurements, observations, examinations, and test results in accordance with the reporting requirements of the inspection or test method(s). Each test or inspection report also shall include the following unless the contractual agreement specifies otherwise:

13.9.1.1 A title, for example, “Report of Reinforced Concrete Inspection,” “Report of Field Moisture and Density Tests;”

13.9.1.2 The name, address, and contact information of the agency;

13.9.1.3 A unique identification of the report (such as report number), the date of issued, a sequential number for each page, and the total number of pages;

13.9.1.4 The name and address of client (physical or electronic) where appropriate;

13.9.1.5 Description of, condition of, and clear identification of the item or area (location) inspected or tested;

13.9.1.6 Date of performance of inspection or test;

13.9.1.7 Identification of inspection and test methods used or clear description of any non-standard method used;

13.9.1.8 Any deviations from, additions to, or exclusions from, the inspection or test method and any other information relevant to a specific inspection, or test, such as environmental conditions;

13.9.1.9 Measurements, observations, examinations, and test results, supported by tables, graphs, sketches, and photographs, as appropriate;

13.9.1.10 A statement to the effect that the results relate only to the items inspected or tested;

13.9.1.11 A statement that the report shall not be reproduced, except in full, without the prior written approval of the agency; and

13.9.1.12 Name(s) of individual(s) performing the inspections or tests;

13.9.1.13 A signature and title, or an equivalent identification, of the person(s) accepting responsibility for the content of the report (however produced) on behalf of the agency; and

13.9.1.14 Identification of results obtained from inspections or tests subcontracted by the agency to others. The agency shall not represent the services of others as its own.

13.9.2 In addition to the requirements of Section 13.9.1, each inspection or test report, where necessary for the proper interpretation or understanding of the report, shall include the following:

13.9.2.1 Project title and reference designation;

13.9.2.2 Reference to relevant specification(s) or requirement(s);

13.9.2.3 A statement indicating compliance with approved project plans and specifications; and

13.9.2.4 Other reporting requirements of the client, the building official, or relevant authority.

13.9.3 In addition to the requirements of Sections 13.9.1 and 13.9.2, test reports presenting results where information on sampling is necessary for the interpretation of the test results shall include the following:

13.9.3.1 Date of sampling or date sample received, as appropriate;

13.9.3.2 Clear identification of the material sampled including manufacturer, brand name, lot number, source, or similar unique information, as applicable;

13.9.3.3 Sampling location, where relevant, using an explicit description, diagram, sketch, or photograph, as applicable;

13.9.3.4 Identification of sampling methods used, or sampling plan or procedure if a non-standard method was used;

13.9.3.5 Deviations from, additions to, or exclusions from standard sampling methods or predetermined sampling plans or procedures; and

13.9.3.6 Details of environmental conditions present during the sampling such as rain that may have affected the testing of the sample or the interpretation of the test results.

13.9.4 When interpretations of tests, inspections, or samplings are included in the report, the basis for the interpretations shall be clearly explained. Interpretations shall include determination of compliance/noncompliance of the results with requirements or fulfillment of contractual requirements.

13.9.5 Material revisions or additions to a report after issue shall be made in the form of a further document clearly indicating the revised information and clearly referencing the original report identification. Such revisions or additions shall meet the relevant requirements of Section 13.9.2.

13.9.6 Transmission of inspection or test reports by electronic means shall follow documented procedures to ensure that the requirements of this chapter are met and that confidentiality is preserved.

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CHAPTER 14—INSPECTIONS AND TESTING OF MATERIALS AND CONSTRUCTION

14.1—Scope

14.1.1 This chapter includes scope and specific requirements relating to testing and inspection of various construction types and materials including concrete, soil and rock, steel, sprayed-fire resistive, installed firestops and masonry construction.

14.1.2 Special Inspections and Tests shall be according to Chapter 17 of SBC 201.

14.2—Concrete Inspection and testing

14.2.1 General

14.2.1.1 Concrete inspection and testing services will normally include some or all of the following: sampling and testing of ingredients, mixture design, checking of production equipment and procedures, inspection of reinforcement and placement, inspection of concrete placement and concrete curing, and laboratory testing of hardened specimens.

14.2.1.2 The agency shall comply with ASTM C1077 for tests of concrete and aggregate.

14.3—Soil and rock inspection and testing

14.3.1 General

14.3.1.1 Soil and rock inspection and testing services will normally include some or all of the following: sampling and testing of in-situ materials, sampling and testing of materials being processed, sampling and testing of processed materials, inspection and testing of soil and rock placement procedures, and sampling and testing of in-place constructed components.

14.3.1.2 The agency shall comply with ASTM D3740.

14.4—Steel inspection and testing

14.4.1 General

14.4.1.1 Steel inspection and testing services will normally include one or more of the following general functions: inspection at source of base material (the steel mill), inspection at fabrication shop, inspection at erection site, laboratory testing to determine physical and chemical properties of steel, laboratory tests of paints for use on steel structures, qualification of welding procedures and personnel, nondestructive testing (radiographic, magnetic particle, liquid penetrant, ultrasonic, etc.), and inspection of cutting and bending of reinforcing bars and testing of same.

14.4.1.2 Personnel performing visual inspection of structural steel or piping shall be familiar with the quality requirements of the particular project and the governing codes or standards. Visual weld inspection shall be performed by an AWS Certified Welding Inspector (AWS-QC-1) except as otherwise allowed by contractual agreement. The inspection of welds shall be supervised or overseen by an AWS Certified Welding Inspector or by a Professional Engineer.

14.4.2 The agency shall be equipped to meet the needs of the procedures required to fulfill the contractual agreement. If the agency subcontracts services to other agencies, these agencies shall be properly equipped.

14.4.3 Reference Material

14.4.3.1 Appropriate references, relevant to the construction being inspected, including the approved project plans and specifications, shall be readily available to the technicians or inspectors at all times. The following are particularly essential.

(a) Applicable parts of Annual Book of ASTM Standards,
(b) Applicable Parts of AISC Manual of Steel Construction,
(c) Applicable Parts of ASME Boiler and Pressure Vessel Code,
(d) Applicable building codes,
(e) AWS D1.1,
(f) AWS B1.11,
(g) AWS D1.5,
(h) AWS D1.4, and
(i) Steel Joist Institute (SJI) Recommended Code of Standard Practice for Steel Joists and Joist Girders.

14.4.4 Laboratory Equipment—The testing agency responsible for testing steel shall be equipped with at least the following:

14.4.4.1 Suitable facilities for preparing test specimens.

14.4.4.2 A screw or hydraulic type of testing machine of sufficient capacity to test the specimen. The machine shall be equipped with suitable gripping and bending tools and with variable speed control. It shall be verified annually in accordance with a procedure specified by ASTM E4 and shall meet the accuracy requirement of these procedures. A report giving detail of the verification shall be readily available.

14.4.4.3 Hardness measuring device (Rockwell or Brinell).

14.4.4.4 Appropriate measuring equipment such as micrometers, rules, dividers.

14.4.4.5 Access to a chemical laboratory suitably equipped for the analysis of constituents and alloying elements of structural steels, and for analysis of paints to applicable specification.

14.4.4.6 AWS standard guided-bend test jig.

14.4.4.7 Bend test jig for reinforcing steel.

14.4.5 Field Equipment (Mill, Fabrication, and Erection)— The agency shall be equipped with the following items of equipment appropriate to the service to be rendered:

(a) Steel tape, rule, calipers, and other appropriate measuring equipment.
(b) Weld dimension gage.
(c) Weld viewing shield.
(d) Hammer for weld testing.
(e) Battery operated hand light.
(f) Paint thickness gage.
(g) Thermometer (or temperature-measuring crayons).
(h) Inspector's identification stamp or tags.
(i) Inspection wrench (a torque wrench used per AISC requirements) for high strength bolts.

14.4.5.1 Tension Calibrator (Tension Measuring Device)— The accuracy of a tension calibrator shall be confirmed through calibration at least annually. Three of the AISC approved methods for installing pretension bolts in slip critical connections do not rely on any torque measurements at all. The turn-of-nut method (favored by AISC), the alternate design fastener method, and direct tension indicator method do not rely on torque measurements, but rather on observing nut rotation, the snap off of a mandrel, or deformation of tension indicators; these methods require initial verification using a tension measuring device.

14.4.6 Qualifications for Nondestructive Testing Agencies— When nondestructive testing is required, the agency performing the testing shall meet in their entirety the requirements of ASTM E543.

14.5—Sprayed fire resistive inspection and testing

14.5.1 General

14.5.1.1 Spray-applied fire-resistive material inspection and testing will normally include some or all of the following services:

(a) Inspection of application, in accordance with the "Inspection Procedures" Section of ASTM E1513.
(b) Testing of thickness and density in accordance with ASTM E605.
(c) Testing of cohesion/adhesion in accordance with Test Method E736.

14.5.2 The agency shall comply with the requirements specified in Sections 13.2 through 13.9 of this Code.

14.6—On-site inspection of installed firestops

14.6.1 General

14.6.1.1 On-site inspection of installed firestops will normally address all types of firestops installed through or onto fire resistive assemblies.

14.6.1.2 A standard practice is provided in ASTM E2174 and ASTM E2393.

14.6.2 The agency shall comply with the requirements in Sections 13.2 through 13.9 of this Code.

14.7—Masonry Inspection and testing

14.7.1 General

14.7.1.1 Masonry inspection and testing services will normally include some or all of the following services:

(a) Sampling and inspecting the raw materials used in the manufacture of masonry units,
(b) Inspecting the manufacture of masonry units,
(c) Sampling and testing masonry units,
(d) Preparing grout and mortar mixture design,
(e) Inspecting and testing the production and placement of grout and mortar, and

(f) Inspecting and testing the reinforcing steel used in masonry construction.

14.7.1.2 The agency shall comply with the most recent edition of ASTM C1093 for tests of masonry, grout, and mortar.

14.8—Nondestructive testing agencies

14.8.1 Nondestructive testing will usually include tests performed by the following methods: Radiographic Testing (RT), Ultrasonic Testing (UT), Liquid Penetrant Testing (PT) and Magnetic Particle Testing (MT).

14.8.2 The agency shall comply with ASTM E543 and to the other requirements specified in Sections 13.2 through 13.9 of this Code.

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