NUCLEAR Design Development

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A new spec provides guidance for using steel-plate composite walls in nuclear facilities.

IN RECENT YEARS, there has been a move to explore modularized construction methods for nuclear power plants to improve overall cost and schedule.

However, the lack of a U.S.-based design code for steel-plate composite (SC) wall construction was a major impediment to the adoption of these types of assemblies in the U.S. But in 2006, AISC formed an ad hoc subcommittee under the Task Committee on Nuclear Facilities to look at current research and initiate the development of design criteria for SC walls. Resulting from this work, the design provisions for SC walls in safety related-nuclear facilities are included in the recently released Supplement No. 1 to *Specification for Safety-Related Steel Structures for Nuclear Facilities* (ANSI/AISC N690-12). For ease of use, the Supplement has been incorporated into the ANSI/AISC N690-12 document (a free download at **www.aisc.org/epubs**).

Modular SC

So what is modular SC construction? SC walls involve concrete walls reinforced with steel faceplates that are anchored to concrete using steel anchors. The faceplates are connected to each other using tie bars and concrete is poured in between the walls. Modular SC construction reduces the project schedule and labor requirements significantly compared to typical reinforced concrete (RC) walls. Faceplates eliminate the requirement of external formwork and reduce congestion in comparison to RC walls by acting as equivalent reinforcement (no massive reinforcing cages). A typical SC wall section is shown in Figure 1.

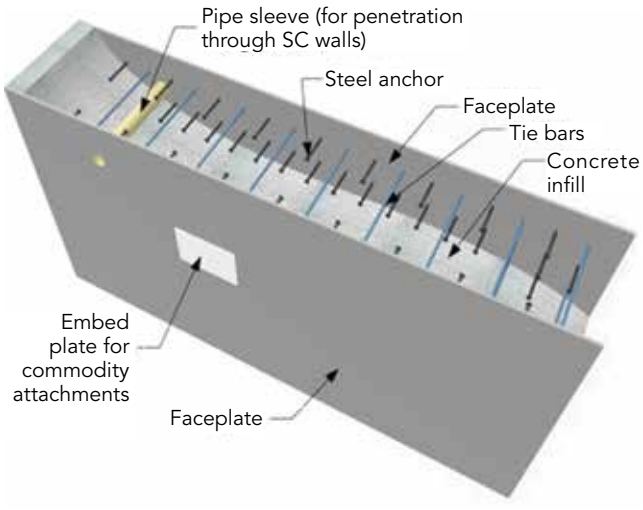

Figure 1. Typical SC wall section.

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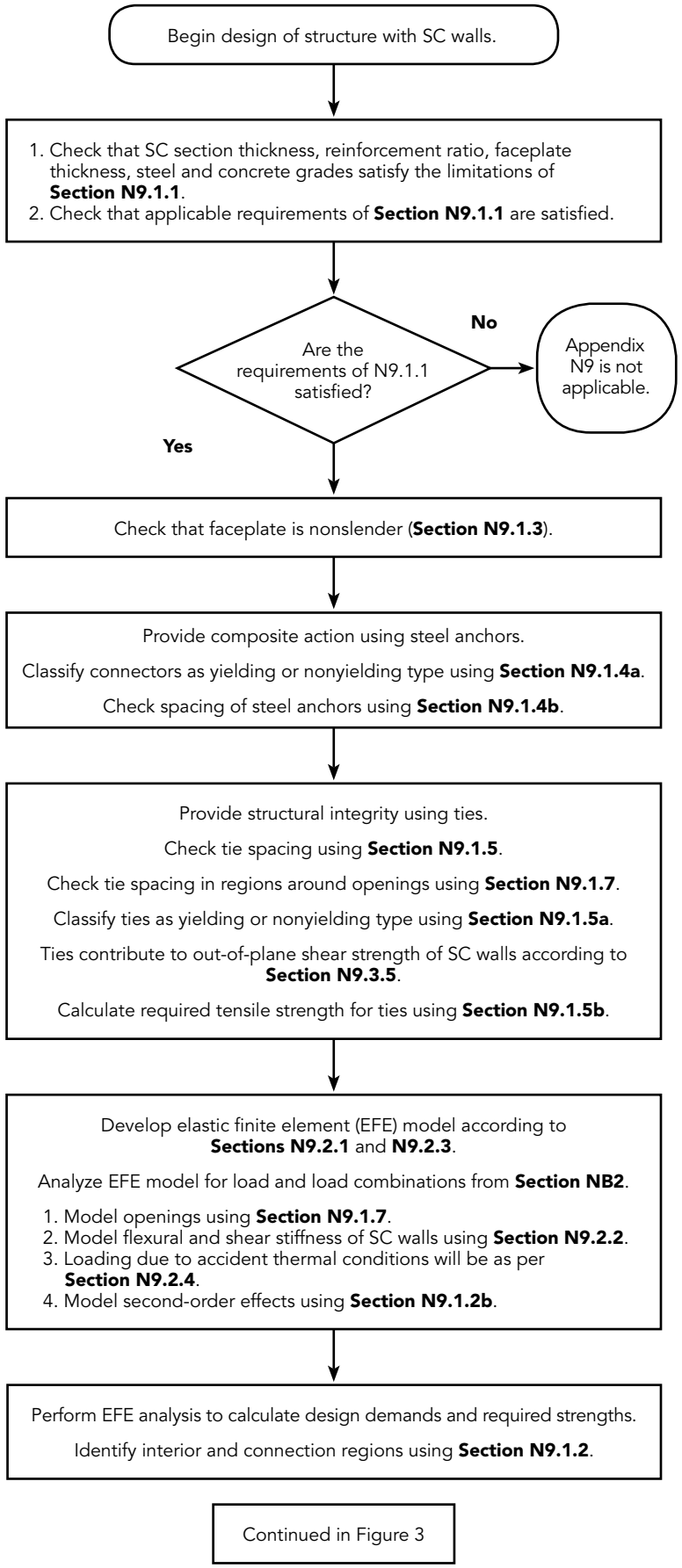
➤ Figure 2. Flowchart to facilitate use of Appendix N9.



Appendix N9 is applicable to the design of SC walls and SC wall connections and anchorages. The experimental database that forms the basis of the provisions is discussed in the commentary to Appendix N9. The appendix is limited to SC walls with two faceplates on exterior surfaces and no additional reinforcing bars. The general requirements of the appendix specify the conditions necessary for applicability of the provisions. Section detailing requirements of the appendix address SC-specific limit states of local buckling, interfacial shear failure, and section delamination.

Organization of Appendix N9

Appendix N9 is organized into four major sections. These sections are further organized into subsections. The sections and subsections of the Appendix are listed as follows:

- N9.1 Design Requirements
  - N9.1.1 General Provisions
  - N9.1.2 Design Basis
  - N9.1.3 Faceplate Slenderness Requirement
  - N9.1.4 Requirements for Composite Action
  - N9.1.5 Tie Requirements
  - N9.1.6 Design for Impactive and Impulsive loads
  - N9.1.7 Design and Detailing Around Openings
- N9.2 Analysis Requirements
  - N9.2.1 General Provisions
  - N9.2.2 Effective Stiffness for Analysis
  - N9.2.3 Geometric and Material Properties for Finite Element Analysis
  - N9.2.4 Analyses Involving Accident Thermal Conditions
  - N9.2.5 Determination of Required Strengths
- N9.3 Design of SC Walls
  - N9.3.1 Uniaxial Tensile Strength
  - N9.3.2 Compressive Strength
  - N9.3.3 Out-of-Plane Flexural Strength
  - N9.3.4 In-Plane Shear Strength
  - N9.3.5 Out-of-Plane Shear Strength
  - N9.3.6 Strength Under Combined Forces
  - N9.3.7 Strength of Composite Linear Members in Combination with SC walls
- N9.4 Design of SC Wall Connections
  - N9.4.1 General Provisions
  - N9.4.2 Required Strength
  - N9.4.3 Available Strength

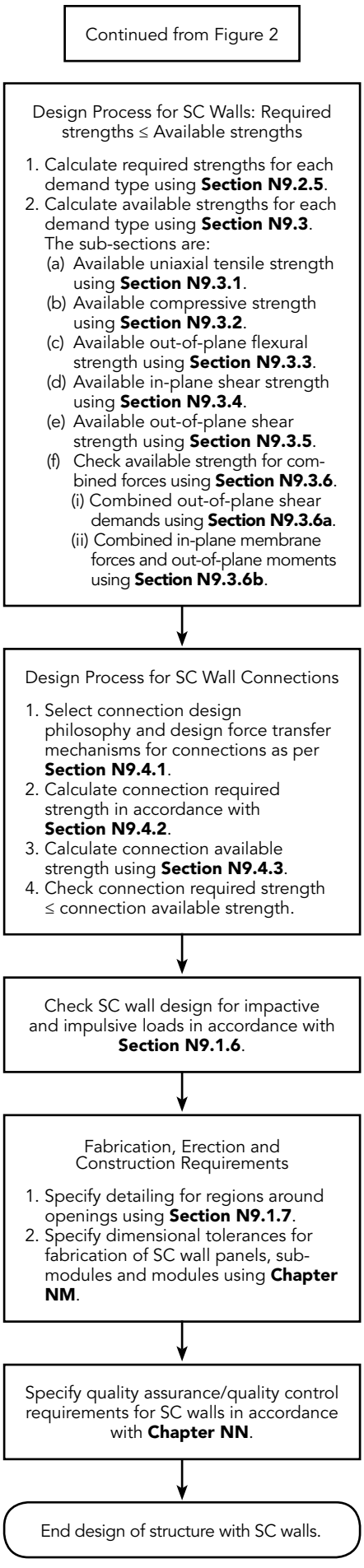


Figure 3. Flowchart to facilitate use of Appendix N9 (continued).

Additions to ANSI/AISC N690-12

In order to incorporate Appendix N9 into ANSI/AISC N690-12, a few additions or updates were made to the existing text of ANSI/AISC N690-12. These modifications include the following:

- American Concrete Institute (ACI), American Society of Mechanical Engineers (ASME) and ASTM International (ASTM) specifications cited in Appendix N9, and not already cited in ANSI/AISC N690-12, have been added to Section NA2.
- ASTM materials for plate cited in Appendix N9, and not already cited in ANSI/AISC N690-12, have been added to Section NA3.
- Section NB2 contains the updated load combinations to consider fluid and soil loads. Load factors for some loads have also been updated based on the U.S. Nuclear Regulatory Commission's Regulatory Guide 1.142.
- A reference to Appendix N9 has been added in Section NB3 for design of SC walls for impactive and impulsive loads.
- Provision for welding of SC wall elements to ASME Class MC components have been added to Section NM2. Dimensional tolerances for SC walls during fabrication, fit up, erection of modules, before concrete placement, and after concrete curing have been provided in Section NM2.
- Inspection requirements for SC walls before and after concrete placement and for welding of faceplates have been provided in Section NN6.

Designing SC Walls Using N9

In order to facilitate the use of Appendix N9, a flowchart has been provided in the commentary to Appendix N9. The flowchart has been reproduced in Figure 2 (previous page) and Figure 3, and discussed briefly below.

In order to design an SC wall structure using Appendix N9, the designer needs to first ensure that the SC wall parameters comply with the requirements of Section N9.1.1. Once these requirements are met, faceplate slenderness requirements of Section N9.1.3 are checked and the steel anchor and tie bar detailing requirements of Sections N9.1.4 and N9.1.5 are then checked. For determining the demands for the SC wall, analysis is performed based on provisions of Section N9.2. The required strengths are compared with available strengths determined per the provisions of Section N9.3. SC wall connections are designed per Section N9.4 using the impactive and impulsive loads per Section N9.1.6. The detailing and fabrication tolerances for SC walls are specified as per Section N9.1.7 and Chapter NM. The quality assurance and quality control of the constructed SC wall is in accordance with Chapter NN.

The development and publication of this new supplement to ANSI/AISC N690-12 provides the first U.S. standard for design and construction of SC wall structures. This will facilitate the use of modular composite construction in nuclear facilities. ■

Supplement No. 1 to Specification for Safety-Related Steel Structures for Nuclear Facilities *is now available for free at* ***www.aisc.org/epubs****. A session on this topic will be presented at the 2016 NASCC: The Steel Conference, which takes place April 13–15 in Orlando (****www.aisc.org/nascc****).*

General Note:
The elastic finite element model should be made using any system of consistent units. The design demands and required strengths are calculated by performing an elastic finite element analysis. However, before using the equations in this Appendix, the units of the calculated design demands and required strengths should be made consistent with the corresponding units in the Appendix equations. For example, the units for design demands and other material parameters used in the equations of this Appendix are as follows:

(a) The required and available out-of-plane moment strengths are in kip-in./ft (N-mm/m).
(b) The required and available membrane in-plane force strengths, and out-of-plane shear force strengths are in kip/ft (N/m).
(c) The modulus of elasticity for steel and concrete are in ksi (MPa).