AN INCREASED INTEREST in improving the resilience and sustainability of nuclear facilities has subsequently increased attention towards optimizing their construction.

An emerging option for such optimization is steel-plate composite (SC) construction. This modular technology leads to shorter construction schedules and provides a robust design for seismic, blast and impact loads.

Here’s how it works: Concrete walls are reinforced with two steel faceplates attached to the concrete using steel anchors, such as steel headed stud anchors, and connected to each other using steel tie bars. The steel faceplates serve as formwork during concrete placement, and through composite action enabled by shear connectors they also serve as equivalent reinforcing steel during the service life of the structure, thus eliminating the need for internal steel reinforcing bars. Ties provide structural integrity, prevent delamination of plain concrete and serve as shear reinforcement.

And now SC is the focus of a new publication: AISC Design Guide 32: Design of Modular Steel-Plate Composite Walls for Safety-Related Nuclear Facilities. In 2015, AISC published the design provisions for SC walls (Appendix N9) in safety related-nuclear facilities as a part of Supplement No. 1 (s1) to the 2012 Specification for Safety-Related Steel Structures for Nuclear Facilities (ANSI/AISC N690-12), available at www.aisc.org/standards, and the newly published

Saahastaran Bhardwaj (sbhardwa@purdue.edu) is a PhD candidate at Purdue University's Lyles School of Civil Engineering and assisted Amit Varma with creating the steel-plate composite wall design provisions and commentary in Appendix N9 of ANSI/AISC N690. Amit Varma (ahvarma@purdue.edu) is a professor at the Lyles School of Civil Engineering. He has served as the vice chair of AISC Task Committee 12: Nuclear Facilities Design and is currently a member of the AISC Committee of Specifications, AISC Task Committee 5: Composite Design and chair of the AISC/AISI Fire Committee.
The design guide is intended for use in conjunction with this spec. Now available at www.aisc.org/dg, it:

➤ Addresses SC walls that meet the requirements of Appendix N9
➤ Provides supplementary recommendations for the design of modular SC structures using the provisions of Appendix N9
➤ Discusses the design of SC wall connections including design philosophies and typical connection details
➤ Presents illustrations explaining the tolerance requirements for construction and fabrication of SC walls

While Design Guide 32 provides primary procedural steps required for the design of SC structures, nuclear construction also needs to satisfy other regulatory and environmental requirements, which may affect the design procedure, as well as project-specific scenarios that need to be considered in the design.

**Layout**

The guide is organized into 14 chapters along with an appendix. Chapter 1 presents background and introductory information for the SC wall system, its advantages and limitations, and summarizes the layout and applicability of AISC N690s1. Chapter 2 discusses design guide scope and layout. The minimum requirements that an SC wall needs to meet for the provisions of Appendix N9 to be applicable are discussed in Chapter 3. The guide then discusses the detailing requirements for SC walls in Chapters 4 through 6. These detailing requirements are provided to address specific SC limit states such as faceplate local buckling. The requirements include faceplate slenderness requirements and steel anchor and tie detailing. Guidelines for modeling and analysis of SC walls are presented in Chapter 7, and the determination and basis of individual design strength equations in follow in Chapter 8, with Chapters 9 and 10 covering demand interaction. Connection design is covered in detail in Chapter 11, where different connection philosophies, force transfer mechanisms and types are presented, along with illustrations, and Chapter 12 provides guidance on impact and impulsive loading.

**Example**

Implementation of the AISC N690s1 provisions is illustrated using a detailed design example presented in Appendix A in the guide. An SC wall from a compartment of a typical safety-related nuclear facility is selected, and all aspects of the design are discussed. The example discusses the rationale for selecting the preliminary details of the structure, and a discussion on the materials selected with their basis is also presented. Representative design demands are considered for the design of the example SC wall, which doesn’t include any attachments or openings.

While the example presents the methodology for designing modular SC walls, the designer should consider the constructability aspect of these walls during the analysis and detailing phases of the design. For example, the size of the prefabricated module should be established based on transportation capabilities. It is also necessary to consider the erection and fabrication loads, concrete casting pressure and demands on ties and ribs prior to casting. Therefore, designers need to be cognizant of the fabrication and erection procedures and sequence to ensure the design can be implemented without any issues. Appendix N9 to AISC N690s1 provides fabrication and erection tolerances that need to be met for the provisions of the appendix to be applicable. These toler-
Begin design of structure with SC walls.

Check that SC section thickness, reinforcement ratio, faceplate thickness, steel and concrete grades and applicable requirements of Section N9.1.1 are satisfied.

Are the requirements of N9.1.1 satisfied?  
NO  
NO

Check that faceplate is non-slender (Section N9.1.3).

Classify steel anchors as yielding or nonyielding type per Section N9.1.4a.  
Check spacing of steel anchors per Section N9.1.4b.

Check tie spacing per Section N9.1.5 or Section N9.1.7.  
Classify ties as yielding or non-yielding per Section N9.1.5a.  
Check required tensile strength for ties per Section N9.1.5b.

Develop elastic finite element (EFE) model per Sections N9.2.1 and N9.2.3.  
Analyze EFE model for load and load combinations from Section NB2.

1. Model openings per Section N9.1.7.  
2. Model flexural and shear stiffness of SC walls per Section N9.2.2.  
3. Loading due to accident thermal conditions will be per Section N9.2.4.  
4. Model second-order effects per Section N9.1.2b.

Perform EFE analysis to calculate design demands and required strengths.  
Identify interior and connection regions per Section N9.1.2.


1. Calculate required strengths for each demand type per Section N9.2.5.  
2. Calculate available strengths for each demand type per Section N9.3.

Design process for SC Wall Connections: Required strength ≤ Available strength.

1. Select design force transfer mechanisms for connections per Section N9.4.1.  
2. Calculate connection required strength based on the connection design philosophy per Section N9.4.2.  
3. Calculate connection available strength per Section N9.4.3.

Check SC wall design for impactive and impulsive loads in accordance with Section N9.1.6.

Check Fabrication, Erection and Construction Requirements per Section N9.1.7 and Chapter NM.

Perform the quality assurance/quality control checks for SC walls in accordance with Chapter NN.

End design of structure with SC walls.