U.S. NUCLEAR REGULATORY COMMISSION

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SAFETY-RELATED STEEL STRUCTURES AND STEEL-PLATE COMPOSITE WALLS FOR OTHER THAN REACTOR VESSELS AND CONTAINMENTS

A. INTRODUCTION

Purpose

This regulatory guide (RG) describes a method acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) for compliance with NRC regulations for the design, fabrication, and erection of safety-related steel structures and steel-plate composite (SC) walls for other than reactor vessels and containments. This guide endorses, with exceptions and clarifications, the procedures and standards of the 2018 edition of American National Standards Institute (ANSI)/American Institute of Steel Construction (AISC) N690, "Specification for Safety-Related Steel Structures for Nuclear Facilities" (Ref. 1).

Applicability

This RG applies to applicants and licensees subject to Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 2), and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 3).

Applicable Regulations

- Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 establishes necessary design, fabrication, construction, testing, and performance requirements for structures, systems, and components (SSCs) important to safety through general design criteria (GDC). GDC applicable to this RG include the following:
  - GDC 1, "Quality standards and records," requires, in part, that SSCs "important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated for applicability, adequacy, and

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sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function."

  - GDC 2, "Design bases for protection against natural phenomena," requires, in part, that SSCs "important to safety be designed to withstand the effects of natural phenomena . . . without loss of capability to perform their safety functions."

  - GDC 4, "Environmental and dynamic effects design bases," requires, in part, that SSCs "important to safety be designed to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents . . . ."

Additional requirements applicable to this RG include the following:

- Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 establishes overall quality assurance (QA) for SSCs important to safety.

- Appendix S, "Earthquake Engineering Criteria for Nuclear Power Plants," to 10 CFR Part 50 states, in part, requirements for the implementation of GDC 2 with respect to earthquakes.

- 10 CFR Part 52 governs the issuance of early site permits, standard design certifications, combined licenses, standard design approvals, and manufacturing licenses for nuclear power facilities licensed under Section 103 of the Atomic Energy Act of 1954, as amended (68 Stat. 919), and Title II of the Energy Reorganization Act of 1974 (88 Stat. 1242).

  - 10 CFR 52.47, "Contents of applications; technical information," provides requirements on the content of technical information for standard design certifications submitted under 10 CFR Part 52.

  - 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report," provide requirements on the technical content of combined operating license applications.

Related Guidance

- RG 1.28, "Quality Assurance Program Criteria (Design and Construction)" (Ref. 4), describes methods that the NRC staff considers acceptable for complying with the provisions of 10 CFR Part 50 and 10 CFR Part 52, which refer to 10 CFR Part 50, Appendix B, for establishing and implementing a QA program for the design and construction of nuclear power plants and fuel reprocessing plants.

- RG 1.29, "Seismic Design Classification for Nuclear Power Plants" (Ref. 5), provides guidance for identifying and classifying features of light-water-reactor nuclear power plants that must be designed to withstand the effects of a safe-shutdown earthquake.

- RG 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants" (Ref. 6), provides guidance that the NRC staff considers acceptable for use in selecting the design-basis tornado and design-basis tornado-generated missiles that a nuclear power plant should be designed to withstand to prevent undue risk to the health and safety of the public.

- RG 1.142, “Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)” (Ref. 7), provides guidance for the design, evaluation, and QA of safety-related nuclear concrete structures, excluding concrete reactor vessels and concrete containments.

- RG 1.199, “Anchoring Components and Structural Supports in Concrete” (Ref. 8), provides guidance for design, testing, evaluation, and QA, including installation and inspection of anchors (steel embedment) used for anchoring component and structural supports on concrete structures.

- RG 1.217, “Guidance for Assessment of Beyond-Design-Basis Aircraft Impacts” (Ref. 9), describes considerations for aircrafts impacts for new nuclear power reactors.

- RG 1.221, “Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants” (Ref. 10), provides new guidance that the NRC staff considers acceptable for use in selecting the design-basis hurricane windspeed and hurricane-generated missiles that a new nuclear power plant should be designed to withstand to prevent undue risk to public health and safety.

- NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition” (Ref. 11) (SRP), provides guidance to the NRC staff in its review of safety analysis reports submitted as part of a license application.

Purpose of Regulatory Guides

The NRC issues RGs to describe methods that are acceptable to the staff for implementing specific parts of the agency’s regulations, to explain techniques that the staff uses in evaluating specific issues or postulated events, and to describe information that the staff needs in its review of applications for permits and licenses. Regulatory guides are not regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs are acceptable if supported by a basis for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Parts 50 and 52, that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et seq.). These information collections were approved by the Office of Management and Budget (OMB), approval numbers 3150-0011 and 3150-0151, respectively. Send comments regarding this information collection to the FOIA, Library, and Information Collections Branch ((T6-A10M), U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, or by e-mail to Infocollects.Resource@nrc.gov, and to the OMB reviewer at: OMB Office of Information and Regulatory Affairs, NEOB-10202 (3150-0011 and 3150-0151), Attn: Desk Officer for the Nuclear Regulatory Commission, 725 17th Street, NW, Washington, DC 20503; e- mail: oira_submission@omb.eop.gov.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the document requesting or requiring the collection displays a currently valid OMB control number.

B. DISCUSSION

Reason for Issuance

This guide provides updated regulatory guidance for the design, fabrication, and erection of safety-related steel structures and SC walls for other than reactor vessels and containments. This guide endorses, with exceptions and clarifications, the procedures and standards of the 2018 edition of American National Standards Institute (ANSI)/American Institute of Steel Construction (AISC) N690, "Specification for Safety-Related Steel Structures for Nuclear Facilities."

Background

The NRC has used former editions of ANSI/AISC N690 for staff guidance. NUREG-0800 refers to ANSI/AISC N690-1994 (Ref. 12), including its Supplement 2 published in 2004 (Ref. 13), in Section 3.8.3, Revision 4, "Concrete and Steel Internal Structures of Steel or Concrete Containments," and Section 3.8.4, Revision 4, "Other Seismic Category I Structures." Since the publication of N690-1994 and its 2004 Supplement 2, ANSI/AISC-N690 has been revised several times, leading to the current 2018 version. ANSI/AISC N690-18 differs significantly from ANSI/AISC N690-1994 and its Supplement 2.

ANSI/AISC N690-18 is compatible with ANSI/AISC 360-16, "Specification for Structural Steel Buildings" (Ref.14). Provisions of ANSI/AISC 360-16 are applicable unless stated otherwise. Only those sections that differ from the ANSI/AISC 360-16 provisions are indicated in ANSI/AISC N690-18.

ANSI/AISC N690-18 addresses updated design approaches, characterization of loads and load combinations, materials, and construction technologies, including SC structures. SC structures involve a modular construction approach that new reactor designs have adopted as one of the major features for some of their structures. The NRC has historically reviewed new reactor applications and license amendments that incorporate the use of SC construction on a case-by-case basis.

In 2015, AISC, through a multiyear effort, issued the first U.S. consensus standard for the design, fabrication, and erection of safety-related SC walls as Appendix N9 to Supplement 1 to the 2012 edition of AISC N690, "Specification for Safety-Related Steel Structures for Nuclear Facilities," namely, AISC N690s1 15 (Ref. 15). ANSI/AISC N690-18 includes Appendix N9.

The NRC Office of Nuclear Regulatory Research contracted with Brookhaven National Laboratory (BNL) to assist the staff with the review of the technical basis for ANSI/AISC N690. As a deliverable, BNL released report BNL-220652-2020-INRE, "Evaluation of the Specification for Safety-Related Steel Structures for Nuclear Facilities, ANSI/AISC N690-18, for Application to Nuclear Power Plants," issued December 2020 (Ref. 16). This report describes the assessment of ANSI/AISC N690-18 for use in nuclear power plants. The report outlines the technical basis for the acceptance of this new specification and the technical background for additional staff guidance.

This guide considers the aforementioned technical background and provides updated regulatory guidance for the design, fabrication, and erection of safety-related steel and SC walls other than reactor vessels and containments. The nuclear industry and the NRC staff can use this new design and review guidance as needed for new reactor designs, including small modular reactors and advanced nonlight-water designs, and the guidance is available for the review of license amendments for operating plants that invoke the new guidance and use SC or steel structures.

Consideration of International Standards

The International Atomic Energy Agency (IAEA) works with member states and other partners to promote the safe, secure, and peaceful use of nuclear technologies. The IAEA develops Safety Standards and Safety Guides for protecting people and the environment from harmful effects of ionizing radiation. These standards and guides provide a system of safety fundamentals, safety requirements, and safety guides reflecting an international perspective on what constitutes a high level of safety. In developing or updating RGs, the NRC has considered IAEA Safety Standards and Safety Guides in order to benefit from the international perspectives.[1]

The following IAEA Safety Guides incorporate similar design and preoperational testing guidelines and are consistent with the basic safety principles considered in developing this Regulatory Guide:

- Safety Guide NS-G-1.5, "External Events Excluding Earthquakes in the Design of Nuclear Power Plants," issued 2003 (Ref. 17)

- Safety Guide NS-G-1.6, "Seismic Design and Qualification for Nuclear Power Plants," issued 2003 (Ref. 18)

- Safety Guide NS-G-2.6, "Maintenance, Surveillance and In-service Inspections in Nuclear Power Plants," issued 2002 (Ref. 19)

- Safety Guide NS-G-3.6, "Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants," issued 2005 (Ref. 20)

- Safety Report 70, Management System Standards: "Comparison between IAEA GS-R-3 and ASME NQA-1-2008 and NQA-1a-2009 Addenda," issued 2012 (Ref. 21)

Documents Discussed in Staff Regulatory Guidance

This RG endorses, in part, the use of one or more codes or standards either developed by external organizations or found in other third-party guidance documents. These codes, standards, and third-party guidance documents may contain references to other codes, standards, or third-party guidance documents ("secondary references"). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in an RG as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific RG. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in an RG, then the secondary reference is neither a legally binding requirement nor a "generic" NRC-approved acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified, consistent with current regulatory practice and consistent with applicable NRC requirements.

[1] Such information related to this guide may be found at www.IAEA.org or by writing the International Atomic Energy Agency, P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria; telephone (+431) 2600-0; fax (+431) 2600-7; or e-mail Official.Mail@IAEA.Org. It should be noted that some of the international recommendations do not correspond to the requirements specified in the NRC's regulations and the NRC's requirements take precedence over the international guidance.

C. STAFF REGULATORY GUIDANCE

This guide endorses the procedures and standards of ANSI/AISC N690-18 for the design, fabrication, and erection of safety-related steel structures and SC walls for other than reactor vessels and containments, subject to the exceptions and clarifications in the regulatory guidance positions below.

1. ANSI/AISC N690-18, Chapter NA—General Provisions

    1.1. Linear piping supports and supports for pressure-retaining components within the jurisdictional boundary of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Subsection NF (Ref. 22) are not within the scope of this RG.

2. ANSI/AISC N690-18, Chapter NB—Design Requirements

    2.1. ANSI/AISC N690-18, Section NB2.5—Load and Resistance Factor Design (LRFD)

Unless otherwise justified, the NRC staff endorses the LRFD load combinations in Section NB2 as modified in Table 1 (modifications indicated in ***bold*** font).

Table 1 Load Combinations for the LRFD Method

LRFD Required Strength (U) Load Combinations	**N690 Equation**
U = 1.4(D + F) + 1.4Ro + To + *1.0*C	NL (NB2-1)
U = 1.2(D + F) + 1.6L + 1.6H + 1.2Ro + *1.2*To + 1.4C + 0.5(Lr or S or R)	NL (NB2-2)
U = 1.2(D + F) + 0.8L + 0.8H + 1.2Ro + *1.2*To + 1.4C + *1.6(Lr or S or R)*	NL (NB2-3)
U = 1.2(D + F) + **1.6**L + 1.6H + 1.2Ro + To + *1.0*W + *1.0C + 0.5(Lr or S or R)*	SEL (NB2-4)
U = 1.2(D + F) + **1.6**L + 1.6H + 1.2Ro + To + 1.6Eo + *1.0*C + *0.2(Lr or S or R)*	SEL (NB2-5)
U = D + F + 0.8L + H + To + Ro + Es + C	EEL (NB2-6)
U = D + F + 0.8L + H + To + Ro + Wt	EEL (NB2-7)
U = D + F + 0.8L + H + Ta + Ra + **1.4**Pa + C	AL (NB2-8)
U = D + F + 0.8L + H + Ta + Ra + Pa + Yr + Yj + Ym + 0.7Es	AL (NB2-9)
NL = Normal Loading SEL = Severe Environmental Loading EEL = Extreme Environmental Loading AL = Abnormal Loading	

2.1.1. Construction loads should be considered in the design of steel structures. These loads consist of dead loads, live loads, temperature, wind, snow, rain, ice, and applicable construction loads, such as material loads, personnel and equipment loads, horizontal construction loads, erection and fitting forces, equipment reactions, and loads from pressure. American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) 37-14, "Design Loads on Structures during Construction" (Ref. 23), describes the minimum design requirements for construction loads, load combinations, and load factors affecting buildings and other structures that are under construction. It addresses partially completed structures as well as temporary support and access structures used during construction.

2.1.2. Hydrodynamic loads associated with seismic loads (i.e., the impulsive and sloshing loads for fluids in tanks) are to be considered as part of Es in load combinations (NB2-6) and (NB2-9). Hydrodynamic loads associated with seismic loads are to be considered as part of Eo in load combination (NB2-5). All other hydrodynamic loads should be taken as Yj in load combination (NB2-9).

2.1.3. Loads resulting from pool dynamics for SC structures in pressure-suppression containments should be analyzed. Licensees and applicants should justify the methods of analysis used.

2.1.4. The design for loads due to accidental explosions, accidental vehicle impacts, or small aircraft impacts should use load combination (NB2-7) with those loads in lieu of Wt, as well as further guidance provided in Appendix N9 to ANSI/AISC N690-18. The Wt load in the load combination (NB2-7) should be evaluated for both tornado and hurricane loads applicable to the site for which related regulatory guidance is covered in RG 1.76 and RG 1.221, respectively. RG 1.217 cover the effects from beyond-design-basis large aircraft impacts, which are outside the scope of this RG.

2.1.5. The codes and standards have not provided a justification for the generic reduction of the load factor from 1.4 to 1.2 (NB2-8). However, uncertainty analysis on the calculation of the design accident pressure can justify the use of a load factor less than 1.4.

2.1.6. In load combination (NB2-9), 0.7Es is to be combined absolutely with the accident loads. In lieu of this, 1.0Es may be combined with the accident loads by the Square-Root-of-the-Sum-of-the-Squares (SRSS), if all the provisions of ANSI/AISC N690-18, Commentary Section NB2.5, Paragraph 4, are satisfied.

2.2. ANSI/AISC N690-18, Section NB2.6, Allowable Strength Design (ASD)

Unless otherwise justified, the NRC staff endorses the ASD load combinations in Section NB2 as modified in Table 2 (modifications indicated in ***bold*** font).

Table 2 Load Combinations for the ASD Method

ASD Required Strength (U) Load Combinations	**N690 Equation**
U = (D + F) + Ro + To + C	NL (NB2-10)
U = (D + F) + **L** + H + Ro + To + C + **1.0**(Lr or S or R)	NL (NB2-11)
U = (D + F) + 0.75L + 0.75H + To + C + **0.75**(Lr or S or R)	NL (NB2-12)
U = (D + F) + **1.0**L + **1.0**H + Ro + To + 0.6W + C + 0.75(Lr or S or R)	SEL (NB2-13)
U = (D + F) + **1.0**L + **1.0**H + Ro + To + Eo + C + 0.75(Lr or S or R)	SEL (NB2-14)
U = D + F + L + H + To + Ro + Es + C	EEL (NB2-15)
U = D + F + L + H + To + Ro + Wt	EEL (NB2-16)
U = D + F + L + H + Ta + Ra + Pa + C	AL (NB2-17)
U = D + F + L + H + Ta + Ra + Pa + Yr + Yj + Ym + 0.7Es	AL (NB2-18)
NL = Normal Loading SEL = Severe Environmental Loading EEL = Extreme Environmental Loading AL = Abnormal Loading	

2.2.1. Load combination NB2-10 has the same loads as NB2-1 and is, essentially, a combination of dead loads. Load combination NB2-11 has the same loads as NB2-2 and is, essentially, a live load combination with L and H as the dominant loads. Load combination NB2-12 has the same loads as NB2-3 and is a live load combination with Lr, or S or R as the dominant loads.

2.2.2. Unless otherwise justified, the allowable strength increase in NB2.6d(8) is limited to 1.5 for load combinations NB2-15 through NR2-18. This reduces the likelihood that the member or fastener strength obtained with the ASD method is not less than the strength that would be obtained with the LRFD method.

2.2.3. Construction loads should be considered in the design of steel structures. These loads consist of dead loads, live loads, temperature, wind, snow, rain, ice, and applicable construction loads, such as material loads, personnel and equipment loads, horizontal construction loads, erection and fitting forces, equipment reactions, and loads from pressure.

2.2.4. Hydrodynamic loads associated with seismic loads (i.e., the impulsive and sloshing loads for fluids in tanks) are to be considered as part of Es in load combinations (NB2-15) and (NB2-18). Hydrodynamic loads associated with seismic loads are to be considered as part of Eo in load combination (NB2-14). All other hydrodynamic loads should be taken as Yj in load combination (NB2-18).

2.2.5. Loads resulting from pool dynamics for SC structures in pressure-suppression containments should be analyzed. Licensees and applicants should justify the methods of analysis used.

2.2.6. The design for loads due to accidental explosions, accidental vehicle impacts, or small aircraft impacts should use load combination (NB2-7) with those loads in lieu of Wt, as well as further guidance provided in Appendix N9 of ANSI/AISC N690-18. The Wt load in the load combination (NB2-16) should be evaluated for both tornado and hurricane loads applicable to the site for which related regulatory guidance is covered in RG 1.76 and RG 1.221 , respectively. RG 1.217 covers the effects from beyond-design-basis large aircraft impacts, which are outside the scope of this RG.

2.2.7. In load combination (NB2-18), 0.7Es is to be combined absolutely with the accident loads. In lieu of this, 1.0Es may be combined with the accident loads by SRSS, if all the provisions of ANSI/AISC N690-18, Commentary Section NB2.5, Paragraph 4, are satisfied.

3. ANSI/AISC N690-18, Chapter NC—Design for Stability

ANSI/AISC 360-16, , Chapter C, referenced in Chapter NC of ANSI/AISC N690-18, is acceptable for design for stability, subject to the following qualifications:

3.1. The provisions of Appendix 7 for the effective length method should only be implemented where all the requirements on its use are clearly satisfied.

3.2. The first order analysis method, using B1 and B2 factors from Appendix 8 to simulate second-order effects, should only be implemented where all the requirements on its use are clearly satisfied.

4. ANSI/AISC N690-18, Chapter NI—Design of Composite Members

   4.1. The methods for design and construction found in RG 1.142, Revision 3, issued May 2020, should be used as applicable for composite members.

   4.2. Consistent with RG 1.142, Revision 3, this RG does not endorse, in general, the use of high-strength steel reinforcing bars (yield strength greater than 60,000 pounds per-square-inch in design (ANSI/AISC N690-18, Chapter NI, on the design of composite members refers to Chapter I of ANSI/AISC 360-16, which allows the use of high-strength reinforcing bars). If high-strength steel reinforcing bars are used, applicants should demonstrate its adequacy for the specific use of the design by testing, analysis, or performance evaluation.

   4.3. The following criteria should be used when applying the direct analysis method of design for structural systems that include encased composite members or filled composite members:

      4.3.1. The provisions in section I1.5 of ANSI/AISC 360-16 for stiffness calculations are acceptable if the findings in Denavit et al. (Ref. 24) for stability sensitive structures are addressed and demonstrated not to be applicable.

      4.3.2. Long-term effects due to creep and shrinkage should be analyzed.

5. ANSI/AISC N690-18, Chapter NJ—Design of Connections

ANSI/AISC 360-16, Chapter J, section J9 refers to Chapter 17 of ACI 318-14 (Ref. 25). Appendix D of ACI 349-13 (Ref. 26) should be used instead of Chapter 17 of ACI 318-14. In addition, requirements in ACI 349-13 should be used along with the regulatory guidance positions in RG 1.199, Revision 1, unless otherwise justified.

6. ANSI/AISC N690-18, Chapter NN—Quality Control and Quality Assurance

RG 1.28 should be used for QA in design, construction, inspection, and testing of steel and composite structures covered by this RG.

7. ANSI/AISC N690-18, Appendix N1—Design by Advanced Analysis

ANSI/AISC N690-18, Appendix N1, on design by advanced analysis, incorporates ANSI/AISC 360-16, Appendix 1, with certain modifications. The following qualifications apply to Appendix N1:

   7.1. Nonlinear inelastic analysis, in accordance with ANSI/AISC N690-18, Section NB3.14, is acceptable to treat impactive and impulsive loads.

   7.2. Nonlinear inelastic analysis, in accordance with ANSI/AISC N690-18, Appendix N1, Section 1.3.1 supplement to ANSI/AISC 360-16, Appendix 1, Section 1.3.1, is acceptable to treat thermally induced local inelastic effects.

   7.3. Nonlinear inelastic analysis, in accordance with ANSI/AISC 360-16, Appendix 1, Section 1.3, is acceptable for the structural evaluation of seismic Category II (nonsafety related) steel structures to address seismic Category II/I interactions. The NRC staff reviews the details of each analysis.

8. ANSI/AISC N690-18, Appendix N3—Design for Fatigue

The upper limit on the allowable stress range used in the design for fatigue should be the lower of (1) the value based on Appendix 3, Section 3.1, of ANSI/AISC 360-16 or (2) the allowable stress range obtained using Equation (A-3-1) in Appendix 3 to ANSI/AISC 360-16.

9. ANSI/AISC N690-18, Appendix N4—Structural Design for Fire Conditions

This RG does not endorse ANSI/AISC N690-18, Appendix N4, on structural design for fire conditions because it is outside the scope of the RG.

10. ANSI/AISC N690-18, Appendix N5—Evaluation of Existing Structures

ANSI/AISC N690-18, Appendix N5, on the evaluation of existing structures, does not address seismic and dynamic loads and, therefore, is not applicable to commercial nuclear power plants. This RG does not endorse Appendix N5. Evaluation of existing structures is not within the scope of this RG.

11. ANSI/AISC N690-18, Appendix N9—Steel-Plate Composite Walls

11.1. ANSI/AISC N690-18, Appendix N9, Section N9.1.6—Design for Impactive and Impulsive loads

Section N9.1.6 and its subsections are based on ACI 349-13, Appendix F, on special provision for impulsive and impactive effects, adapted to SC walls. The NRC staff considers the provisions in Section N9.1.6 and its subsections acceptable with the additions and exceptions proposed below:

11.1.1. Impactive and impulsive loads are assumed to be concurrent with other loads (e.g., dead and live loads) in determining the required strength of structural elements.

11.1.2. For impulsive loads, the strength available is at least 20 percent greater than the magnitude of any portion of the impulsive loading, which is approximately constant for a time equal to or greater than the first fundamental period of the structural member.

11.1.3. In addition to the deformation limits under 11.1.4. to 11.1.7. below, the maximum deformation should not result in the loss of intended function of the structural wall nor impair the safety-related function of other systems and components.

11.1.4. For flexure-controlled SC walls as defined in Section N9.6b of ANSI/AISC N690-18, the permissible displacement ductility ratio demand should satisfy all of the following:

- ductility ratio less than or equal to 10,
- principal strain of the faceplates less than or equal to 0.05 (Johnson et al., 2014) (Ref. 27), and
- rotational capacity of any yield hinge less than or equal to 0.07 radians (4 degrees) (Bruhl et al., 2017, Ref. 28).

11.1.5. For SC walls resisting axial compression, the permissible displacement ductility ratio should be as shown in 11.1.5.1 to 11.5.1.3:

11.1.5.1. When compression controls the design as defined by the balanced point in a load-moment interaction diagram, the permissible ductility ratio should be 1.0.

11.1.5.2. When the compression load is less than $0.1(f'_c A_g)$, where A_g is the sum of the area of concrete infill and the net area of the faceplates, or one-third of that which would produce balanced conditions, whichever is smaller, the permissible ductility ratio should be as given in 11.1.4.

11.1.5.3. The ductility ratio varies linearly between 1.0 and that given in 11.1.4 for conditions between those described in 11.1.5.1 and 11.1.5.2.

11.1.6. The permissible displacement ductility ratio in flexure should not exceed 3.0 for loads such as internal blast overpressure and compartment pressurization, which could affect the integrity of the structure as a whole. Flexural deformations of the compartment walls or slabs associated with ductility ratios greater than 3.0 can be justified by assuring the structural integrity of the structure. The justification should consider the impulsive loads originating from within the pressurized compartment including the follow-on pressurization that may remain inside the compartment and act as sustained loads depending on the compartment venting as well as all other loads acting concurrently with the impulsive loads and the follow-on compartment pressurization.

11.1.7. For shear-controlled SC walls with yielding shear reinforcement spaced at section thickness divided by two or smaller, the ductility ratio is no greater than 1.3. For shear-controlled SC walls with yielding shear reinforcement spaced in excess of the section thickness divided by two or for shear-controlled SC walls with nonyielding reinforcement, the ductility ratio is limited to 1.0. Higher ductility factors up to the values in ANSI/AISC N690-18, Section N9.6b should be justified on a case-specific basis.

11.1.8. The shear strength under local loads considers reaction shear at the supports and punching shear adjacent to the load.

11.1.8.1. Local loads may be impulsive or impactive, except that, for impactive loads, satisfaction of criteria for perforation should be used in place of punching shear requirements.

11.1.8.2. The shear strength is determined in accordance with the provisions in Section N9.3, on the design of SC walls, of ANSI/AISC N690-18, using the appropriate dynamic increase factors in Table A-N9.1.1 for the required concrete and steel material properties.

11.1.8.3. In the case of the reaction shear (beam action condition) at the supports, the effective width of the critical section for the shear beam capacity at the supports is to be determined according to the zone of influence induced by the local loads instead of the entire width of the support. The zone of influence induced by the concentrated loads may be determined, for example, by an analysis (Ref. 29).

11.1.9. Design of SC walls or SC structural wall systems for impactive loads should meet the criteria for local effects and overall structural response. The overall structural response is determined by the methods for impulsive loads in Section N.9.1.6c. Local effects include penetration, perforation, and punching shear. The penetration depth as well as the concrete and faceplate thickness required to prevent penetration are from applicable rational methods or pertinent test data together with the conditions in N9.1.6c of ANSI/AISC N690-18 for the faceplate thickness.

11.1.10. Evaluation of loads from malevolent, beyond-design-basis, aircraft impacts are within the scope of RG 1.217 and are outside the scope of this RG.

11.2. ANSI/AISC N690-18, Appendix N9, Section N9.2.5—Determination of Required Strengths

Section N9.2.5 specifies that the required strength for each member load type may be determined by averaging the demand over areal extents of the wall (referred to as "panel sections") that are less than or equal to twice the wall thickness in length and width, except at connections and openings, where the panel section dimensions are limited to the wall thickness. These averaging guidelines are acceptable in conjunction with recommendations in the commentary to N9.2.1.2. Other conditions will be reviewed on a case-specific basis.

11.3. ANSI/AISC N690-18, Appendix N9, Section N9.3.2—Compressive Strength

Equation A-N9-16, provided for calculating the compressive strength of SC walls, should be used for surface temperatures up to 300 degrees Fahrenheit (150 degrees Celsius), consistent with the recommendation made in Section N9.3.2 of the commentary. For temperatures above this threshold, the basis for the analytical approach should be demonstrated.

11.4. ANSI/AISC N690-18, Appendix N9, Section N9.3.5—Out-of-Plane Shear Strength

The term tensile strength, F_t, to be used in Equation A-N9-23, should be determined in accordance with ANSI/AISC N690-18 Chapter ND.

11.5.ANSI/AISC N690-18, Appendix N9, Section N9.3—Design of SC Walls

Appendix N9 does not include design provisions for attachments to SC walls. The design of the SC walls should consider the need for localized strengthening of the SC wall steel module or additional anchorage, or both, to be installed before pouring concrete to provide adequate support for large, heavy attachments. In addition, loads from smaller attachments mounted directly to the faceplates after construction of the SC walls (e.g., field run conduit and piping) should be considered where applicable. The effects of elevated temperature in the concrete due to the welding of attachments to the faceplate after the concrete has cured should also be considered.

12. Editorial Corrections

To ensure the proper use of the provisions in ANSI/AISC N690-18, the editorial corrections given below should be followed:

- In Table NB3.2, for the information missing in the column under the heading "Example" for unstiffened elements, the sketches shown in Table NB3.2 of N690-12 should be used.

- The title for Figure C-A-N9.1.21 in Section N9.1.7a of the Commentary to ANSI/AISC N690-18 should be identified as “Small circular opening – detailing illustration for fully developed edge with flange plate thickness < $1.25t_p$.”

- The definitions for two parameters used in Equations A-N9-8 and A-N9-8M in Section N9.2 of ANSI/AISC N690-18 should be identified as follows:

  - c_2 = calibration constant for determining effective flexural stiffness.

  - $\overline{\rho}$ should be replaced with ρ' in the definition for the stiffness-adjusted reinforcement ratio.

D. IMPLEMENTATION

The NRC staff may use this RG as a reference in its regulatory processes, such as licensing, inspection, or enforcement. However, the NRC staff does not intend to use the guidance in this RG to support NRC staff actions in a manner that would constitute backfitting as that term is defined in 10 CFR 50.109, “Backfitting,” and as described in NRC Management Directive 8.4, “Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests,” (Ref. 30), nor does the NRC staff intend to use the guidance to affect the issue finality of an approval under 10 CFR Part 52. The staff also does not intend to use the guidance to support NRC staff actions in a manner that constitutes forward fitting as that term is defined and described in Management Directive 8.4. If a licensee believes that the NRC is using this RG in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfitting or forward fitting appeal with the NRC in accordance with the process in Management Directive 8.4.

REFERENCES [2]

1. American National Standards Institute (ANSI)/American Institute of Steel Construction (AISC), "Specification for Steel-Related Steel Structures for Nuclear Facilities," ANSI/AISC N690-18, Chicago, IL, June 2018[3].

2. *U.S. Code of Federal Regulation,* "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter 1, Title 10, "Energy."

3. *U.S. Code of Federal Regulation*, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter 1, Title 10, "Energy."

4. U.S. Nuclear Regulatory Commission (NRC), "Quality Assurance Program Criteria (Design and Construction)," Regulatory Guide (RG) 1.28.

5. NRC, "Seismic Design Classification," RG 1.29.

6. NRC, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants," RG 1.76.

7. NRC, "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)," RG 1.142.

8. NRC, "Anchoring Components and Structural Supports in Concrete," RG 1.199.

9. NRC, "Guidance for the Assessment of Beyond-Design-Basis Aircraft Impacts," RG 1.217.

10. NRC, "Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants," RG 1.221.

11. NRC, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," NUREG-0800.

12. ANSI/AISC, "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities," ANSI/AISC N690-1994, Chicago, IL, 1994.

13. ANSI/AISC, "Supplement No. 2 to the Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities (ANSI/AISC N690-1994(R2004))," ANSI/AISC N690-1994(R2004)s2, Chicago, IL, October 2004.

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2 Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html The documents can also be viewed online or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD. For problems with ADAMS, contact the PDR staff at 301-415-4737 or (800) 397-4209; fax (301) 415-3548; or e-mail pdr.resource@nrc.gov.

3 Copies of reports from the American Institute of Steel Construction (AISC) are available through their web site https://www.aisc.org/ or by contacting their home office at 130 East Randolph Street, Chicago, IL 60601, telephone (312) 670-2400.

16. Brookhaven National Laboratory (BNL), "Evaluation of the Specification for Safety-Related Steel Structures for Nuclear Facilities, ANSI/AISC N690-18, for Application to Nuclear Power Plants," Report BNL-220652-2020-INRE, Upton, NY, December 2020. ADAMS Accession No. ML21007A005.

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19. IAEA, "Maintenance, Surveillance and In-service Inspections in Nuclear Power Plants," Safety Guide NS-G-2.6, Vienna, Austria, 2002.

20. IAEA, "Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants," Safety Guide NS-G-3.6, Vienna, Austria, 2005.

21. IAEA, Management System Standards, "Comparison between IAEA GS-R-3 and ASME NQA-1-2008 and NQA-1a-2009 Addenda," Safety Report 70, Vienna, Austria, 2012.

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27. Johnson, William H., J. Bruhl, D.G. Reigles, J. Li, and A. Varma, "Missile Impact on SC Walls: Global Response," Structures Congress, Boston, MA, April 3–5, 2014.

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[4] Copies of American Society of Mechanical Engineers (ASME) standards may be purchased from ASME, Two Park Avenue, New York, New York 10016-5990; telephone (800) 843-2763. Purchase information is available through the ASME Web-based store at http://www.asme.org/Codes/Publications/

[5] Copies of reports from the American Society of Civil Engineers (ASCE) are available through their Web site (https://www.asce.org), or by contacting their home office at American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA, 20191; telephone (800) 548-2723.

[6] Copies of ACI publications may be purchased from ACI, 38800 Country Club Dr., Farmington Hills, MI 48331-3439, telephone (248) 848-3700. Purchase information is available through the ACI Web site at https://www.concrete.org

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