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Safety-Related Steel Structures and Steel-Plate Composite Walls for Other Than Reactor Vessels and Containments

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General Comment

The attached file is the American Institute of Steel Construction comments concerning Regulatory Guide DG-1304

Attachments

AISC Comments Regulatory Guide DG-1304

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March 25, 2021

Office of Administration
Mail Stop: TWFN-7-A60M
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
Attention: Program Management, Announcements, and Editing Staff

Docket ID NRC-2021-0038

The Federal Register notice of February 10, 2021 addressed a draft Regulatory Guide DG-1304 which was being issued for initial public comments. Public comments were requested to be submitted by March 29, 2021. The draft regulatory guide is entitled "Safety-Related Steel Structures and Steel-Plate Composite Walls for Other Than Reactor Vessels and Containments."

DG-1304 endorses, with exceptions and clarifications, the 2018 edition of American National Standards Institute (ANSI)/American Institute of Steel Construction (ANSI/AISC N690), "Specification for Safety-Related Steel Structures for Nuclear Facilities." The Nuclear Specification (N690) is compatible with the 2016 edition of American National Standards Institute (ANSI)/American Institute of Steel Construction (ANSI/AISC 360), "Specification for Structural Steel Buildings," and uses it as the baseline document, modifying portions of it as necessary to make it applicable to the design, fabrication, and erection of safety-related steel structures for nuclear facilities. The comments that follow in this letter address the draft regulatory guide. These comments are being submitted by AISC.

In general, AISC welcomes the creation of the regulatory guide. AISC has been campaigning for the NRC to adopt this latest edition of the specification since a regulatory guide currently does not exist which specifically concerns ANSI/AISC N690-18. AISC also hopes that with the issuance of the regulatory guide, a vehicle has been put in place wherein future editions of this AISC specification will be reviewed and adopted by the NRC.

Please address any questions on the following comments to the undersigned.

Yours truly,

American Institute of Steel Construction
Lawrence F. Kruth, PE
Vice President of Engineering and Research

Cc: Ronald Janowiak, Jonathan Tavarez
Attachments: Comments of Draft Regulatory Guide DG-1304 (6 pages)
Review of Draft Regulatory Guide by Professor Bruce Ellingwood (3 pages)

Comments on Draft Regulatory Guide DG-1304:

"Safety-Related Steel Structures and Steel-Plate Composite Walls for Other Than Reactor Vessels and Containments"

The following comments are being submitted by the American Institute of Steel Construction.

1. In Section A of the draft Regulatory Guide, 10 CFR Part 50 and 10 CFR Part 52 are referenced, but no reference is made to 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, Reactor-Related Greater than Class C Waste." The draft Regulatory Guide should include this reference since ANSI/AISC N690-18, including Steel-Plate Composite (SC) construction, may be used in these applications.
2. The draft Regulatory Guide should also apply to Research and Test Reactors, and Fuels and Materials Facilities.
3. There appears to be an inconsistent use of "AISC 360-16" versus "ANSI/AISC 360-16." The appropriate designation is the latter, i.e. ANSI/AISC 360-16. Please correct Sections C.4.2, C.4.3.1, C.5, C.7, C.7.2, C.7.3, C.7.4, C.7.5, C.8, and C.11.4 of the draft Regulatory Guide.
4. Section A of the draft Regulatory Guide lists RG 1.29. The text uses the phrase "must be." Since this document is listed under Related Guidance, the phrase should be changed to "should be."
5. ASCE 43-19 should be included in the section of Related Guidance, as well as the References.
6. Editorial: In Section C.1.2 of the draft Regulatory Guide, revise "N690 s1-15" to "ANSI/AISC N690s1-15."
7. Section C.1.2 of the draft Regulatory Guide adds the requirement for UT testing of welded connections (in ANSI/AISC N690-18 Sections NA3.1c and NA3.1d) that are susceptible to lamellar tearing. UT testing is not required since these provisions are focused on the need for the responsible party to develop a plan to mitigate lamellar tearing so that no UT testing is needed. UT testing will identify a delamination/discontinuity if there is enough loss of back reflection to identify the discontinuity. Lamellar tearing can occur on a plate that passes a through thickness UT exam. The concern is that if the UT exam is mandated and the plate passes, then the possibility of lamellar tearing created because of a highly constrained joint design will not be addressed and can occur. Also, as an editorial comment, in the last sentence, change "NA31.c" to "NA3.1c."
8. AISC has asked Professor Bruce Ellingwood to perform an independent review of Table 1, "Load Combinations for the LRFD Method." AISC has reviewed his report and agrees with his recommendations and comments. His report is included as an attachment to this letter.
9. Editorial: Suggest to add "(LRFD)" at the end of the title for Section C.2.1 of the draft Regulatory Guide.
10. In Section C.2.2.6 of the draft Regulatory Guide, revise "N690-18" to "ANSI/AISC N690-18;" also, in the first sentence of this section, correct "NB2-7" to "NB2-16."
11. Sections C.3.1 and C.3.2 of the draft Regulatory Guide are generally agreeable. First, please note that Appendix 7 is for the "effective" length method, and not the "equivalent" length method. The wording "and minimum judgment is required to determine K" in Section C.3.1 is vague and may be subject to interpretation. With the exception of textbook definitions of end conditions (e.g. pinned, free, or fixed), the determination of effective length factors almost always requires some significant degree of judgement. One may argue that the use of alignment charts is pretty straight forward, but it is rare that all ten of the assumptions for using this approach are satisfied for most design conditions encountered – as a result, adjustments in the use of the alignment charts are often required and such adjustments require judgement. Does requiring "minimum judgement" mean that the effective length method can only be used for pinned,

free, or/and fixed end conditions? Or is "minimum judgement" extended to equally rare conditions satisfying all assumptions that correspond to the use of the alignment charts. In either case, such a definition of "minimum judgement" would severely limit the use of a design method that has been successfully used in the U.S. since the early 1960's. We do agree that it is essential that care must always be taken in computing reasonable effective length factors. With this in mind, the first part of the sentence in Section C.3.1 alone should suffice, and we suggest deleting the second part related to using minimum judgment.

12. With respect to Section C.3.3 of the draft Regulatory Guide, AISC questions its validity. First, it is not clear where prediction of elastic stability using the direct second-order analysis method appears or used in the ANSI/AISC 360-16 Specification. The Specification does have a design method termed the direct analysis method (DM) that accounts for the five most significant effects for steel structures that are known to impact stability (see ANSI/AISC 360-16 Section C1 as referenced from ANSI/AISC N690-18 Chapter NC). This design method ensures the stability of structures and its elements. One of these effects includes consideration of second-order effects (P-Δ and P-δ), which most often results in the use of a second-order elastic analysis. Further Section C.3.3 could be misleading because: i) In addition to including the effects of geometric nonlinearity and initial imperfections, DM also considers stiffness reduction due to inelasticity (another one of the five effects mentioned above) via the use of EI* and EA*, both of which are approximations accounting for potential inelasticity; ii) Realistic stress states, and the corresponding degree of yielding, are not known from the analysis; iii) An instrumental part of the DM method is to provide required strengths (e.g. forces and moments and not stresses) for the design of members and connections by elastic analysis under factored loads, with such demands often in excess of first-yield conditions per AISC's limit states design philosophy; iv) Unless a rigorous second order analysis is performed, which is not a requirement of DM as it is defined in ANSI/AISC 360-16 Chapter C (noting that approximate methods of analysis, such as B1 and B2 analyses, are permitted), equilibrium and compatibility may not necessarily be satisfied on the deformed geometry. Thus, the stress state at the onset of instability can't be determined or assessed from the typical analysis used in the DM design method. It is further noted that limiting stresses to only be elastic within the analysis would essentially prohibit any members or components from yielding to any degree under loads factored to the strength limit-state level – a requirement that would be unreasonably conservative. It is AISC's opinion that the application of the DM method (per Chapter C) does not require engineers to verify if the stresses in structure are elastic at the onset of instability and therefore recommends that the draft Regulatory Guide Section C.3.3 be removed.
13. ACI codes are adopting 80,000 psi as the new limit for high strength steel reinforcement. The ACI 349 Code Committee has approved 80,000 psi and it is expected to be a part of the next edition of the ACI 349 Code. Section C.4.2 of the draft Regulatory Guide should adopt this higher limit.
14. Section C.4.3.1 of the draft Regulatory Guide needs to provide criteria and discussion why stability sensitive structures are a concern to the NRC staff.
15. Section C.4.3.2 of the draft Regulatory Guide should provide guidance on how to address long-term effects since AISC standards do not address this potential concern.
16. Editorial: In the title for Section C.5 of the draft Regulatory Guide, revise to "ANSI/AISC N690—18, Chapter NJ – Design of Connections." Corrections are also required in Section C.11.1, C.11.2, C.11.3, and C.11.4.
17. Section C.5 of the draft Regulatory Guide indicates that an exception to ANSI/AISC N690-18 Chapter NJ is required because it should refer exclusively to ACI 349 and not ACI 318. The draft Regulatory Guide also states that the "requirements" in ACI 349-13 should be used along with the regulatory provisions of RG 1.142 Revision 3, and RG 1.199 Revision 2, unless otherwise justified. AISC comments that many facilities are designed to ACI 318, and to limit its use to ACI 349 would be restrictive. Additionally, AISC comments that generically referring to the "requirements" of ACI 349 is rather vague and could lead to misinterpretation. AISC proposes that no exception be taken in the draft Regulatory Guide against Chapter NJ.

18. Unlike in the DM method, stability analysis per ANSI/AISC N690-18 Appendix N1 that is based on ANSI/AISC 360-16 Appendix 1, Section 1.2, requires the use of a rigorous second order analysis, which can indicate whether or not the structural system or any of its components approach instability. However, it still requires consideration of residual stresses and stiffness reduction due to potential yielding. It also requires the analysis be with loads factored to the strength limit-state level. As per our above comments of the draft Regulatory Guide Section C.3.3, design would be unreasonably conservative if stresses under factored loads at the onset of instability must be kept at or below an elastic limit. Thus, the elastic stress requirement of draft Regulatory Guide Section C.7.4 is not appropriate and AISC suggests it be removed.
19. Draft Regulatory Guide Section C.7.5 appears trivial and perhaps unnecessary, unless there is concern that engineers need to be reminded that ANSI/AISC 360-16 Appendix 1, Section 1.3, modified in accordance with ANSI/AISC N690-18 Appendix N1, Section N1.3, is acceptable for use in the design of safety-related steel building structures. It is noted that the inelastic stability analysis of Section 1.3 is the most sophisticated second order analysis available, and is typically reserved by designers for assessing complex and/or overstressed structures. It is clear from the provisions appearing in Section 1.3 that the analysis shall take into account: second order effects, geometric imperfections, material nonlinearity, member and connection ductility and deformation capability.
20. Section C.9 of the draft Regulatory Guide indicates that the use of ANSI/AISC N690-18 Appendix N4 will not be endorsed. However, no alternative guidance is provided, nor is any basis of not accepting Appendix N4 is provided. This guidance should be provided in the draft Regulatory Guide.
21. The following discussion and comments pertain to Section C.11.1.6 of the draft Regulatory Guide:

    Revision 3 of RG 1.142 is based on ACI 349-13. Accordingly, this response references the relevant sections of ACI 349-13. It is acknowledged that RG 1.142 takes exceptions to Section F3.5 of ACI 349-13. In particular, it permits local ductility up to 3.0, but requires that the structure should remain elastic (although it is unclear as to how this can be accomplished). Also, when shear controls, the ductility ratio is limited to 1.3 and 1.0 when shear reinforcement is and is not provided, respectively (note that the additional exceptions related to ACI 349-13 Section F3.8 are not relevant for a compartment pressurization situation since it does not cause horizontal compression load in the compartment walls). The following response takes these exceptions into account.

    The commentary for ACI 349-13 Section F3.5 indicates that the reduced ductility limit of 3 (from 10) has to do with the effect of compartment pressure loading on the compartment's overall structural integrity such that there is a need to minimize the level of permanent deformation. It is understood that response at higher ductility ratio manifests in increased permanent deformation as well as more degraded condition for RC compartment walls (especially in the vicinity of their vertical edges where significant cracking and spalling can occur due to lack of ties and confinement). Aside from structural integrity concerns, such state of permanent deformation, likely accompanied by significant cracking and spalling, can be problematic from the compartment's functionality standpoint. This limitation is necessary for RC compartments because ACI 349 does not require special detailing at a compartment's corners (e.g., increased rebar development length and/or lack of ties); the presence of direct tension and flexure leads to severe cracking/spalling as the rebars undergo large tensile strains associated with increased ductility ratio.

    In contrast to ACI 349, ANSI/AISC N690-18 Section NB3.14 requires the connections to be designed for full expected strength of the connected members (or with significant overstrength); also, ties are required in SC walls (typically the ties and shear connectors are more closely spaced within the connection region). These features and the resulting confining action enhance the SC compartment's structural integrity. For SC walls, aside from absence of crack control related concerns, the prospect of spalling under large strains is also entirely prevented because of the presence of faceplates. For these reasons, unlike RC compartment walls, the SC compartment walls need not be subjected to reduced ductility limitation (i.e., ductility limit of 10, which is explained below, remains appropriate for all SC applications).

[As an aside, it is noted that ACI 349 Section F3.3 permits the limit of 10 for doubly-reinforced RC beams and walls/slabs (except for compartment applications, for which ACI 349 Section F3.5 limits the ductility ratio to 3). This provision is quite applicable to SC walls, and ANSI/AISC N690-18 therefore simply (conservatively) adopted it. This is because SC sections are doubly reinforced with equal reinforcement on both faces (and it is on the exterior in the form of faceplates); this arrangement essentially prevents the prospect of flexure-induced concrete crushing due to increasing tensile strain on the tension reinforcement (i.e., this cross-sectional/curvature related ductility consideration, which is particularly relevant to singly-reinforced cross-sections, is less of a concern for doubly-reinforced sections, especially ones with equal reinforcement). It is further noted that the presence of small-to-moderate magnitude of simultaneous membrane tension force due to compartment pressurization does not adversely impact the cross-sections flexural/rotational ductility because the tension force it continues to ensure that the behavior is controlled by steel yielding, rather than by concrete crushing.]

The following rationale is provided regarding why ANSI/AISC N690-18 Section N9.1.6b does not adhere to the RG 1.142 exception concerning differentiation between local and global ductility. When subjected to internal pressurization, compartment walls experience significant flexure in combination with low-to-moderate membrane tension forces (as explained above, an SC wall's behavior is steel-controlled and hence quite ductile against these force effects at a cross-section level). Each wall will encounter the following sequence of plastic hinge formation before a mechanism state is formed for that wall: hinges at ends (negative moment regions), followed by a hinge along midspan (the walls will essentially behave like a collection of adjoining beam segments that span horizontally). It is noted that the mechanism state at an individual wall level is not immediately tantamount to sudden failure because the rotational ductility of the midspan hinge is not necessarily exhausted (this is especially true for dynamic/short-lasting load). A global mechanism state will be reached only after all four walls of the compartment have formed the three hinges in each wall segment (furthermore, all walls can simultaneously reach their individual mechanism state only if the compartment is doubly symmetric). Compared to this backdrop, the ductility provisions of Section N9.1.6b are written in terms of displacement ductility, which will have to be evaluated for each wall segment. Accordingly, the real question is whether a displacement ductility ratio of 10 can lead to (or exceed) the response state associated with the mechanism formation for an SC wall segment (and even if it does, will that lead to the mechanism state for the compartment as whole). This concern is in turn related to the limitation imposed in Section F3.5 of ACI 349-13 because of a concern about the extent of permanent deformations and the degraded wall condition that can occur for RC walls. In contrast, because they are equally reinforced in tension and compression, SC walls can support very large curvature and rotational ductility that would equal or exceed a comparable RC beam. Being that the ductility limit of 10 is acceptable for a doubly-reinforced beam, it follows that the same should be conservatively acceptable for SC wall in a compartment application. It is expected that each constituent wall segment of the compartment will be below its mechanism state this response ductility level (and thus the compartment on the whole will be at a response state that is below its global mechanism state).

Regarding ductility limits for shear-controlled walls, the following comments are provided:

It is important to note that there is no such thing as SC wall without cross-ties (i.e., the ties are required as part of the standard's General Requirements). As such, the accompanying ductility limits are predicated on whether the ties are ductile and spaced at less than or equal to half the wall thickness. A ductility limit of 1.6 is imposed for the condition when the associated shear failure is steel controlled and hence reasonably ductile (as evidenced from numerous SC specimens tested as beams in four-point test setups). The ductility ratio is limited to 1.3 for situations with non-ductile ties and/or when the tie spacing is in excess of half the wall thickness. This is considered reasonable because of the expected overstrength since the corresponding out-of-plane shear capacity provision is conservative (this is due to the expected overstrength since a shear-

controlled section signifies that the shear span-to-depth ratio must be quite small, whereby as seen from Figure C-A-N9.3.6(a), the concrete resistance to out-of-plane shear increases due to the strut-and-tie action).

Finally, there is no basis provided in the draft Regulatory Guide for reducing the ductility ratios to 1.3 and 1.0 in Section C.11.1.7.

22. The following discussion and comments refer to Section C.11.2 of the draft Regulatory Guide:

    The User Note to ANSI/AISC N690-18 Section N9.2.1(a) refers the designer to the accompanying commentary for analysis guidelines (as well as the refined modeling requirements around openings provided in Section N9.1.7). The commentary recommends that at least four to six elements should be used along the short direction of a wall panel, and six to eight elements along its long direction (this guidance is further illustrated in Fig. C-A-N9.2.9, which also clarifies that the element size for elements in the connection region is to be less than or equal to the SC wall thickness). Because of these provisions/guidelines, it is unlikely that an analyst will use only a few panel sections for modeling a wall panel, and therefore no further caution is deemed necessary in the draft Regulatory Guide. Hence, ANSI/AISC N690-18 stipulated an upper limit of demand averaging equals to 2xtsc in the interior regions and 1xtsc in connecting regions and around openings. See Figure C-A-N9.2.9. The ANSI/AISC N690-18 code committee provided these rules in order to minimize evaluation on a case-specific basis which potentially would result in a high number of requests from NRC to applicants/licensees for additional information (RAI), a situation that the new Regulatory Guide wants to avoid.
23. Section C.11.4 of the draft Regulatory Guide should refer back to ANSI/AISC N690-18 Chapter ND instead of ANSI/AISC 360-16 Chapter D.

Review of U.S. NUCLEAR REGULATORY COMMISSION
DRAFT REGULATORY GUIDE DG-1304, dated February, 2021
(Proposed new Regulatory Guide 1.243
SAFETY-RELATED STEEL STRUCTURES AND STEEL-PLATE COMPOSITE WALLS FOR OTHER THAN REACTOR VESSELS AND CONTAINMENTS[1]

by
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March 6, 2021

Introduction

Draft Regulatory Guide DG-1304 endorses the procedures and standards of *ANSI/AISC Standard 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 a number of exceptions and clarifications, which were developed from Report *BNL-220652-2020-INRE*[1]. One of the exceptions concerns the recommended load combination requirements for Load and Resistance Factor Design. These load combinations are presented in Table 1: Load Combinations for the LRFD Method, of Section C – Staff Regulatory Guidance.

I reviewed and submitted extensive comments on the previous BNL Report in May, 2020. Most of my previous concerns have been addressed in the revised BNL report and the Draft RG DG-1304 developed from it. I will focus my comments on the Load Combinations in Table 1, which were addressed in Section 4.3 of the BNL report. I will not address the proposed load combinations for that appear in Table 2 for the ASD Method because these should be consistent with those for LRFD.

Analysis of load combinations in ANSI/AISC N690-18 Chapter NB and DG-1304

Both AISC N690-18 and Draft RG DG-1304 contain nine load combinations. Three are for "normal" load combinations, two are for "severe environmental load combinations," and four are for "combinations of extreme environmental loads and/or abnormal loads."

The combinations in AISC N690-18 and Draft RG DG-1304 are similar but differ in a number of aspects. The differences appear to arise from the adoption of some of the load factors from ACI 349-13 and RG 1.142. To the best of my knowledge, the LRFD load requirements in ACI 349-13 and RG 1.142 are not based on a rational reliability analysis; at least, I have never seen one published in the archival literature. Furthermore, as the BNL authors note, there is not a compelling reason for the LRFD load requirements to be consistent for both steel and reinforced concrete structures in nuclear plants because of differences in

[1] This Draft Regulatory Guide was developed based on the recommendations in *BNL-220652-2020-INRE (December 2020)*, *Evaluation of the Specification for Safety-Related Steel Structures for Nuclear Facilities, ANSI/AISC N690-18, for Application to Nuclear Power Plants*, a revision of a previous report by the same title: BNL-211992-2019-INRE.

the significance of loads and their uncertainties. Finally, the BNL report offers no justification for the adoption of the RG 1.142 values. These observations are elucidated below.

(1) Normal load combinations:

- Combination NB2-1: This combination deals with permanent operating loads. The load factor on R_o is 1.4 in AISC N690 and 1.0 in DG-1304. In my opinion, a load factor of 1.0 is not adequate to account for uncertainties in pipe reactions under normal operating conditions, including start-up and shut-down based on various transient conditions.

- Combination NB2-2: This combination addresses maximum operating live loads. Since the load combinations are based on a principal action/companion action approach to probabilistic load combinations, $1.2R_o$ is sufficient in this combination, especially if $1.4R_o$ appears in NB2-1. The load $1.6R_o$ is conservative and no evidence has been presented that it is needed for plant safety.

- Combination NB2-3: This combination addresses maximum roof loads. There is absolutely no rationale for reducing $1.6R_o$ to $0.8R_o$ in this combination; they should be the same in both combinations NB2-2 and NB2-3 (i.e., $1.2R_o$), as they are in AISC N690.

(2) Severe environmental load combinations:

- Combination NB2-4: This combination addresses maximum non-tornadic winds (with a return period of 3,000 years for Risk Category IV structures in *ASCE Standard 7-16*). $1.6L + 1.6R_o$ appear as companion actions in this equation. The implication is that the maximum live load and maximum pipe reaction occur at the same time as the 3,000-yr return period wind, which is nonsense. In AISC N690, these loads are 0.8L + 1.2Ro, which are consistent with the reliability analyses performed three decades ago at BNL.

- Combination NB2-5: This combination addresses the OBE earthquake, and its companion actions have exactly the same deficiency as those on combination NB2-4.

(3) Extreme environmental and abnormal load combinations

- Combination NB2-8: The load factor on accidental pressure has been increased from 1.2 to 1.4. I see no rationale for this increase; 1.2 also appears in ACI 349-13 and in several ASME standards as well. However, there may be some more recent information that I am not aware of to support this increase.

Additional comments

I have reviewed statements 2.1.1 - 2.1.5 which appear below Table 1 in Draft RG 1304 and agree with them. I have three additional comments, which are tangentially related to the proposed load combination requirements. I noted these previously in my May 5, 2020 report, and would like to emphasize them:

- **5d(2)** states that if the structural effect of differential settlement is significant, it shall be included with the dead load. I do not agree with this requirement. While the load factor may or may not be the same (see, e.g., Commentary C2.3.4 of ASCE 7-16), differential settlement is a self-straining structural action similar to creep or shrinkage, whereas dead load is force-controlled. Thus, their fundamental characteristics and structural effects are different, even if the load factors are the same, and engineers should not be encouraged to think of them as equivalent; they are not.

- Fluid pressure, F, is treated the same as a dead load in the N690 load combinations. I suggest that you revise **5d(3)** and **5d(4)** to state that if F acts to stabilize the structure against the destabilizing effects of lateral force or uplift, F shall be equal to zero.

- Load H includes loads due to weight and lateral pressure of soil, ground water pressure, or pressure of bulk materials. If H acts to stabilize the structure, H shall be equal to zero.

Summary and recommendations

The load combinations appearing in ANSI/AISC N690-18 are based loosely on research that I conducted at BNL in the mid-1980's with Reich and Shinozuka, as well as an independent study that I performed under contract for Sargent & Lundy. Both sets of combinations have a probabilistic basis and I see no technical basis for revising them, based on the information presented in either BNL report that I've reviewed.