SUPPLEMENTAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/27/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 905-6311 REVISION 3**
SRP SECTION:	**03.08.03 – Concrete and Steel Internal Structures of Steel or Concrete Containments**
APPLICATION SECTION:	**3.8.3**
DATE OF RAI ISSUE:	**01/25/2012**

QUESTION NO. 03.08.03-77:

Section 6.0 of the MHI Technical Report (TR) MUAP-11019-P (R0) discusses the development of design equations for the out-of-plane shear strength of SC walls. The concrete contribution (Vc) to the shear strength of a structural member depends on the direction (tension or compression) of the axial load applied to the member, as shown in the ACI code for RC structures and by the recommended corresponding equations for SC walls. To ensure the design for out-of-plane shear strength for SC members is acceptable, the following information is needed:

1. For equation 6.2-3 presented in Section 6.2 for SC members subjected to axial tension load, a note similar to the one given in ACI 349-06 Section 11.3.2.3 should be added, i.e., “but not less than zero, where Nu is negative for tension.”

2. Section 6.4 of the report states that “as mentioned in ACI 349-06 Section 11.3.1.3, in the presence of significant axial tension, the out of plane shear strength can be calculated by considering the contribution of the shear reinforcement (Vs) alone and neglecting the contribution (Vc) of the concrete." Clarify what is meant by the phrase “can be calculated,” i.e., explain what approach is used in the design of the out of plane shear strength for all of the APWR SC walls when tension loads exist. Explain whether Vc is always conservatively neglected for all out-of-plane shear strength calculations, or is equation 6.2-3 sometimes used to consider the effect of the magnitude of the axial tension force. If it is the latter, then confirm that both plus and minus member forces due to seismic loadings are considered which would eliminate or diminish the benefit of using Equation 6.2-3

3. If any of the three equations 6.2-1, 6.2-2, and/or 6.2-3 will be used to include the shear strength from the concrete infill, then explain why reducing the factor from 2.0 to 1.5 for Vc is adequate. Based on Figure 6.2-1 of the TR, the use of the 1.5 factor does not result in a lower bound to the data points for shear strength provided by concrete for sections corresponding to 36 inches or more (which match the SC section thicknesses).

4. In addition to Section 6.4 discussed above, there are several other locations in the TR where the phrase “can be estimated,” “can be used,” “can be calculated,” or “may be used” …. are utilized. As example, p 2-4 of the TR states that “The maximum axial compressive

strength of the US-APWR SC modules can be estimated according to ACI Equation 10-2 shown in Figure 2.2-2. To avoid confusion, the wording should be revised to state definitively whether this approach or equation(s) are used or only sometimes used because the phrases indicate “can be…” or “may be…”

ANSWER:

This answer supplements the previous MHI answer that was transmitted on March 29, 2013 by letter UAP-HF-13064 (ML13107B428). The supplemental response presented below was discussed with the Nuclear Regulatory Commission (NRC) staff during the Design Certification Document (DCD) Tier 2, Section 3.8 Audit conducted during the week of November 4, 2013. For clarity, the response is repeated below and the supplemental information regarding the out-of-plane shear strength contribution of concrete (V_c) follows.

This answer revises and replaces the previous MHI answer that was transmitted by letter UAP-HF-12108 (ML12138A217).

Technical Report MUAP-11019, Rev. 1, has been updated to incorporate the above changes. Specifically, Equation 6.2-3 in Technical Report MUAP-11019, Rev. 1, has been updated to clarify that V_c shall not be taken as less than zero; the phrase “can be calculated” in the first sentence of Section 6.4 has been replaced with “is calculated,” the remaining discussion in this Section has been reworded to clarify the intended approach; and the phrases “can be” and “may be” have been revised to be prescriptive when defining the design approach to be used throughout the Technical Report.

Confirmatory tests performed using full-scale, (48-inch) thick SC wall specimens representative of the US-APWR design have demonstrated that the out-of-plane shear strength estimated using the equations in Technical Report MUAP-11019, Rev. 1, Section 6 is conservative. The results of the confirmatory, full-scale tests are presented in Technical Report MUAP-11013, Rev. 2, Appendix B, Section 9.0.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on S-COLA

There is no impact on the S-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

There is no impact on the Technical/Topical Report.

SUPPLEMENTAL INFORMATION:

DCD 3.8 Audit item 14A: RAI 905-6311 Question 03.08.03-77 should be revised to include Reliability Analysis Results.

Section 6.4 of Technical Report MUAP-11019, Rev. 1, will be modified as attached to clarify that Equation 6.2-3 is used to consider the effect of the magnitude of the axial tension force when determining V_c.

The experimental database of out-of-plane shear tests conducted on SC wall specimens was presented in Technical Report MUAP-11005, Rev. 1, Appendix B. The database includes tests conducted in Japan, S. Korea, China, and the US. The large-scale out-of-plane shear tests conducted on the US-APWR SC walls are presented in Technical Report MUAP-11013, Rev. 2, Appendix B. The specimens in the database and the US-APWR SC wall tests are categorized based on their failure mode as specimens with shear failure, flexure-shear failure, flexural yielding, and interfacial shear failure. There are 39 specimens with shear failure or flexure-shear failure. Figure 03.08.03-77-1 shows comparisons of the test results (V_{exp}) with the nominal shear strength ($V_{n\text{-}MUAP}$) predicted using Technical Report MUAP-11019, Rev. 1, equations 6.2-1 through 6.2-4. In this Figure, specimens with shear reinforcement are shown with filled symbols, and specimens with flexure-shear failure are shown using grey symbols. In the Figure, specimens T.S.1, T.S.2a, T.S.2b, and T.S.2c were tested in the US, of which the US-APWR tests with shear failure are T.S.2c identified as Test Series 2.1 in Technical Report MUAP-11013, Rev. 2, Appendix B.

Figure 03.08.03-77-1 Shear strength normalized with respect to design equation vs. shear span-to-depth ratio

Reliability analysis was conducted to assess the strength reduction (ϕ) factor for the SC out-of-plane shear database. Equation 03.08.03-77-1 was used to estimate the ϕ factor.

Impact on DCD

There is no impact on the DCD.

Impact on R-COLA

There is no impact on the R-COLA.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical Report

Section 6.4 of Technical Report MUAP-11019, Rev. 1, will be modified as shown in Attachment 1.

This completes MHI's response to the NRC's question.

Figure 6.3-1 Comparison of Tested vs. Calculated Shear Strength

6.4 Shear Strength Contribution (V_s) of Tie Bars

As stated in ACI 349-06 Section 11.3.1.3 (excerpt shown in Figure 6.1-1), in the presence of significant axial tension (greater than 500 psi on the gross section area or 288 kip/ft. on a 4 ft. thick section) the out-of-plane shear strength is calculated by considering the contribution of the shear reinforcement (V_s) alone and neglecting the contribution (V_c) of the concrete. ~~For simplicity and conservatism, this approach is automatically applied when checking the US-APWR SC wall out-of-plane shear strength for load cases involving seismic loading.~~

According to Section 11.5.7.2 of ACI 349-06 (excerpt shown in Figure 6.1-1), the contribution of the tie bars (V_s) to the shear strength of a unit foot wide section having **[** 4 ft. depth, 0.5 in. x 6.0 in. A572 Gr. 50 tie bars at 24 in. spacing **]** is computed using Equation 11-15 in ACI 349-06 as:

The concrete contribution to out-of-plane shear strength is reduced for load cases which result in axial tension in accordance with ACI 349-06 Section 11.3.2.3 and MUAP-11019 Equation 6.2-3.