RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

05/31/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 985-6948 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:	**01/08/2013**

QUESTION NO. 03.08.03-107:

The staff reviewed the applicant's response to RAI 905-6311 Question 03-08.03-76 regarding the equations used for the moment capacities of steel-concrete (SC) walls. The staff notes that the MHI design approach for flexural strength is conservative because it neglects the compression steel. The MHI approach for calculating the moment capacity including compression steel is also conservative because the flexural strength is based on the yield strain of the steel in tension, as compared to the American Concrete Institute (ACI) code where the flexural strength generally corresponds to a steel tensile strain well beyond the yield strain. However, for calculating the out-of-plane shear strength, the MHI approach is to ensure that the shear strength is greater than the shear force corresponding to the flexural strength without considering compression steel. Therefore, the staff requests that the applicant use appropriate upper bound flexural strength values for the determination of the out-of-plane shear strength required for the SC wall connection region, as discussed in Section 3.1 of TR MUAP-11020-P (R0). Otherwise, provide an alternative approach to demonstrate the SC design philosophy that the flexural limit state controls the design. In addition, considering that axial compression force may increase the flexural strength of an SC wall, explain whether an appropriate axial compression load needs to be considered in determining the flexural strength to be used in the out-of-plane shear strength design of the SC wall connection region.

If there will be any change to the MHI out-of-plane shear strength design approach, revise the technical report to incorporate, and revise the DCD to summarize, the important design approach information provided in the RAI response.

ANSWER:

Calculation of Required Out-of-Plane Shear Strength

As discussed in Technical Report MUAP-11020, Rev. 1 Section 3.1, the US-APWR steel-concrete (SC) walls are detailed such that:

As discussed in Technical Report MUAP-11019, Rev. 1 Sections 6.2 and 6.3, the available out-of-plane shear strength ($\phi_v V_{no}$) of SC walls is calculated using more conservative equations for the concrete contribution (V_c) than those recommended by American Concrete Institute (ACI) 349-06. These conservative equations account for the effects of size on the contribution of concrete (V_c) to the out-of-plane shear strength.

Thus, the US-APWR SC walls are detailed with an appropriate estimation of the upper bound flexural strength (M_r) of the SC walls, and an appropriate lower bound (factored) estimation of the available out-of-plane shear strength ($\phi_v V_{no}$). This is confirmed by the results of the confirmatory test program conducted on US-APWR SC wall and connection designs, and discussed in detail in Technical Report MUAP-11013, Rev. 1 Appendix B Section 1. The test results for full-scale Specimens 2.2.1 and 2.2.2 confirm that flexural yielding is the governing limit state for specimens with shear span ratios of 2.

Consideration of Axial Compression

The US-APWR SC walls are detailed such that their out-of-plane shear strength is greater than their upper bound flexural strength developed over a shear span ratio of 2. This is a detailing requirement that is used to design the details (e.g., tie bar size and spacing, shear stud size and spacing, etc.) of US-APWR SC wall cross-section. It is not a Load and Resistance Factor Design (LRFD) requirement.

LRFD requires the available strengths (ϕR_n) of the SC walls to be greater than or equal to the load effects ($\Sigma\gamma_i Q_i$) calculated for the design load combinations. The load effects for SC walls consist of eight design forces, which include three membrane forces, three out-of-plane moments, and two out-of-plane shears. The LRFD check for each of the eight individual design forces is performed according to Sections 3 - 7 of Technical Report MUAP-11019, Rev. 1. The LRFD check of combinations of the eight design forces is done in accordance with Section 8 of Technical Report MUAP-11019, Rev. 1. The design approach presented in Section 8 explicitly considers the effects and interactions of different forces including axial compression, moment, in-plane shear etc. This design approach is used to assess the adequacy of the entire SC wall including the connection regions and interior regions, which are detailed identically to each other.

Thus, the effect of axial compression is considered along with all other load effects (design forces) in the design check for combined forces. It is not considered separately in the detailing requirements because it is one of the eight possible forces (load effects). This axial compression increases not only the flexural strength but also the out-of-plane shear strength and the in-plane shear strength of SC walls.

The detailing of the SC wall cross-section is done to achieve ductility to the extent possible. The requirement of out-of-plane shear strength being greater than the upper bound flexural strength developed over a shear span ratio of 2 is one such detailing requirement, and it is implemented in the absence of axial force to design the SC wall cross-section details (e.g., tie bar size and spacing, shear stud size and spacing etc.).

The LRFD design check for the SC walls is performed for all combinations of design forces.

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

There is no impact on the Technical/Topical Report.

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