RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

03/29/2013

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. 03.08.03-67:

1. As indicated in MHI Technical Report (TR) MUAP-11019-P (R0), the key design philosophy for steel-concrete (SC) walls includes the prevention of SC specific failure modes and limit states by designing and detailing the section adequately. One of the potential SC specific failure modes is local buckling of the steel faceplates. The TR concludes that the SC specific limit state of steel faceplate local buckling is prevented by designing or detailing plate slenderness (defined by s/t_p where s = shear connector spacing and t_p = plate thickness) to be less than or equal to 20 everywhere in the containment internal structure (CIS). As discussed in Section 2.2 of the TR, this conclusion is based on a test performed on several specimens that were subjected to axial compression. It appears that the test subjected the specimens to compressive loads but did not consider the additional expansion effects of the steel plates due to operating and accident temperature loading. MHI Technical Report (TR) MUAP-11005-P (R0) does describe some tests performed on SC members considering temperature effects to determine whether buckling occurs; however, these tests do not appear to include compressive loads. Therefore, the staff requests that the applicant discuss the combined effects of temperature and axial loading on steel faceplate local buckling and whether additional tests are needed to consider the combined effects.

2. As discussed above, Section 2.2 of the subject TR made reference to MHI Technical Report (TR) MUAP-11005 (R0) for the compressive test of several specimens to examine buckling. However, this specific test could not be located in TR MUAP-11005 which contains over 16 different test papers. Therefore, in this case and in other cases, whenever a reference is made to a test report or paper, the applicant is requested to clearly identify where the report/paper is located.

3. Due to (a) the limited number of test specimens (five) shown on page 2-2 in TR MUAP-11019-P, (b) the question of similarity of the test specimens to the US-APWR SC members, and (c) the potential test scale effects, the applicant is requested to also perform a calculation for the US-APWR specific design configuration of the SC members to support the test results and to demonstrate the conservatism of the slenderness ratio design criteria to preclude local buckling.

4. The results of the 1/10 scale test, such as those presented on page 2-11 of MHI TR MUAP-10002-P (R0), indicate that buckling failures occurred in various SC walls of the test model during the test. Considering that the 1/10 scale test model has a steel faceplate slenderness ratio of 18, explain whether or not the buckling failures occurred in the 1/10 scale test model are local buckling failures in the steel faceplates of the SC walls. If so, this would not be consistent with the design criteria for slenderness ratio of 20 to preclude local buckling; and therefore, the applicant is requested to justify the conservatism of the selected design criteria.

ANSWER:

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

1. Technical Report MUAP-11005, Rev. 1, Appendix D, discusses the experimental data obtained from local buckling testing on steel concrete (SC) walls. This data was obtained from tests by Sekimoto, et al, on SC wall specimens with steel plate s/tp ratios of 12.4, 18, and 45. Data was also obtained from tests by Usami, et al., on specimens with steel plate s/tp ratios of 20, 30, 40 and 50, and from tests by Kanchi, et. al., (1996) on SC wall specimens with s/tp ratios of 20, 25, 30, 40, and 50. All of these tests were conducted by subjecting SC wall specimens to axial compression loading. The complete documents for these references have been provided in Technical Report MUAP-11005, Rev. 1, Appendix E.

   The tests by Sekimoto, et al., also subjected specimens to thermal loading with full or complete restraint of the steel faceplates. These tests were conducted on SC specimens with s/t_p ratios of 12.4, 18, and 45. The plates were heated until local buckling occurred due to the compression strains resulting from the restraints to the steel faceplates. Specimens with s/t_p ratio of 45 buckled after heating with a ΔT of 100°C. Specimens with s/t_p ratios of 12.4 and 18 did not buckle even after heating with a ΔT of 300°C.

   Technical Report MUAP-11013, Rev. 2, Section 6 of Appendix A, summarizes the benchmarked analysis that was performed to investigate the combined effects of temperature and axial loading on steel faceplate local buckling. The benchmarked numerical models predicted the local buckling behavior of SC wall specimens in the test database, including those specimens subjected to axial loading only and to thermal loading (with restraints). The resultant benchmarked analytical models are used to confirm the behavior of SC wall specimens with US-APWR specific s/t_p ratios and tie bars subjected to combined axial compression and thermal loading. The analyses confirm the applicability of the selected slenderness ratio limit to both normal and accident thermal loading conditions.

2. The test report by Kanchi, et al., (1996) is provided as Reference 15 of Technical Report MUAP-11005, Rev. 1. The full document is provided in Technical Report MUAP-11005, Rev. 1, Appendix E.

3. As discussed in the response to Question 1, Technical Report MUAP-11013, Rev. 2, Section 6 of Appendix A, confirms the applicability of the selected slenderness ratio limit to both normal and accident thermal loading conditions.

4. The selected steel face plate slenderness ratio (s/tp) prevents face plate local buckling before yielding. This is based on American Institute of Steel Construction (AISC) 360 Specifications for design of steel columns, where column sections with noncompact steel plates (flanges and webs) are selected to ensure that the plates undergo yielding in compression before the occurrence of local buckling.

   The steel plates used in the $1/10^{th}$ scale containment internal structure (CIS) test had a slenderness (s/t_p) ratio of 18. As such, they were also selected to be noncompact, i.e., to undergo yielding first and then local buckling. The test results indicate that the steel plate walls undergo yielding first, and then with increasing plastic strains undergo local buckling. Technical Report MUAP-10002-P, Rev. 0, discusses this in detail. The consistent behavior exhibited by the $1/10^{th}$ scale test and the specimens described in Part 1 of this response that had slenderness ratios less than or equal to 20 demonstrates that this slenderness ratio limit is appropriate for use in the CIS design.

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.

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