RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

07/08/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 1024-7053 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:	**04/26/2013**

QUESTION NO. 03.08.03-114:

The staff reviewed the applicant's response to RAI 931-6467, Question 03.08.03-86, regarding MUAP 11020 (R0), on the full strength connection design example provided in MUAP 11020 (R0) Section 7.

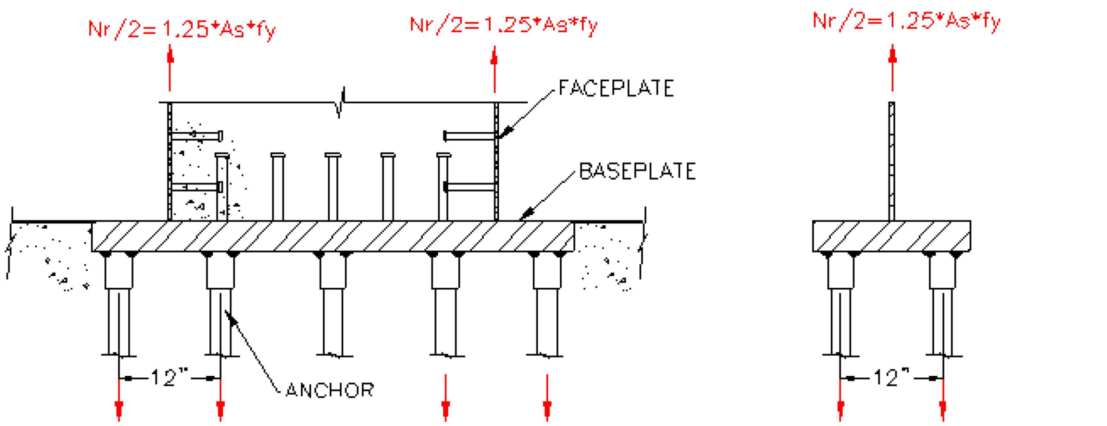
In the response to Item 3, the applicant indicated that the concrete supporting the 3.5 in. baseplate is more flexible than the steel plate in the steel to steel bolted plate connection, and the 10 ft. long #18 rebar anchors will undergo considerable stretching; therefore, prying action effects are neglected for the US-APWR steel concrete (SC) wall anchorage design. This explanation does not justify why baseplate flexibility would not occur for SC wall connections, since baseplate flexibility is a function of a number of design parameters that include the stiffness of the concrete, configuration of the baseplate (size and thickness), number and location of the anchors, edge distance, etc. Also, US-APWR DCD Section 3.8.4.2, which is referenced by Section 3.8.3.2 of the DCD, indicates that RG 1.199 (November 2003) will be used in the design of anchorage to the concrete structure. Regulatory Position 5 of RG 1.199 states that, "Loads and forces on embedments should be properly evaluated to account for baseplate flexibility ..." Therefore, the staff requests that the applicant specify that the design basis identified in the DCD, with respect to RG 1.199, will be followed, and thus, baseplate flexibility will be considered unless it is clearly demonstrated to be not applicable for particular connection designs.

The staff also reviewed the revised response to RAI 931-6467, Question 03.08.03-86, submitted March 29, 2013, and MUAP-11020, Revision 1, submitted February 27, 2013, and determined the issue still applies.

ANSWER:

MHI acknowledges the importance of accounting for baseplate flexibility in determining forces on embedments, as stated in Regulatory Guide (RG) 1.199 Regulatory Position 5. It is feasible that in certain cases involving thin baseplates with relatively wide anchor spacing, deformation of the baseplate due to tension applied by the connected member could cause increased tension (prying force) in the embedded anchors.

The manner in which baseplate flexibility has been addressed in the steel concrete (SC) wall basemat anchorage connection is in accordance with United States industry practice for steel baseplate design, as represented in American Institute of Steel Construction (AISC) Design Guide 1, “Base Plate and Anchor Rod Design” (2^{nd} Edition.) This practice accounts for specific design parameters such as the baseplate size and thickness and the number and location of the anchors relative to the connected member. Section 3.2 of AISC Design Guide 1 states that neglecting prying forces in anchor rods is “usually justified when the baseplate thickness is calculated assuming cantilever bending about the web and/or flange of the column section, as described in Step 3”. Step 3 states, “For tensile loads, a simple approach is to assume the anchor rod loads generate bending moments in the baseplate consistent with cantilever action about the web or flanges of the column section (one-way bending)” and that “the effective bending width for the baseplate can be conservatively approximated using a 45^{o} distribution from the centerline of the anchor rod to the face of the column flange or web.” As illustrated in Figure 03.08.03-114-1 below, this is the methodology used for the containment internal structure (CIS) SC wall basemat anchorage connections to conservatively calculate the baseplate moment demand that is used to determine the required baseplate thickness. It is noted that the anchors resisting tension are arranged symmetrically with respect to the SC wall faceplate. The calculation using the moment developed in the figure results in a baseplate thickness of 3.5 in.



$$L = 12in$$

$$\frac{N_r}{2} = 1.25 \cdot A_s \cdot f_y = 1.25 \cdot 0.5in \cdot 12in \cdot 50ksi = 375kip/ft$$

$$M_{u\_baseplate} = \frac{1}{2} \cdot \frac{N_r}{2} \cdot \frac{L}{2} = \frac{375kip \cdot 12in.}{4} = 1125kip \cdot in/ft$$

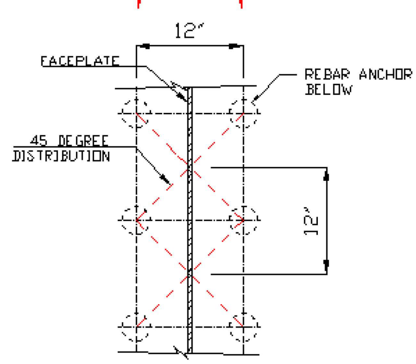


Figure 03.08.03-114-1: Calculation of Baseplate Moment for SC Wall Basemat Anchorage

Importantly, the baseplate thickness calculation has also been performed in accordance with the full strength design methodology, wherein all connectors such as the baseplate are required to transfer the full expected strengths of the connected SC wall. In accordance with Technical Report MUAP-11020, Rev. 1, Section 3.1, the required tensile strength (N_r)

considered in the baseplate thickness calculation is equal to the tension force associated with the full expected tensile strength of the SC wall as well as the full expected flexural strength of the connected SC wall. As shown above, this tension force is equal to 1.25*A_s*F_y or 375 kips per foot of faceplate for the ½-in.-thick faceplates connected to the basemat in all US-APWR SC wall basemat anchorage connections. As a result of this approach, the design ensures that in the event of beyond-design basis events, ductile faceplate yielding and resulting energy dissipation will occur before the code allowable baseplate flexural capacity is reached. This approach further ensures that significant baseplate deformations causing prying forces on the anchors cannot occur, even in the event of overloads.

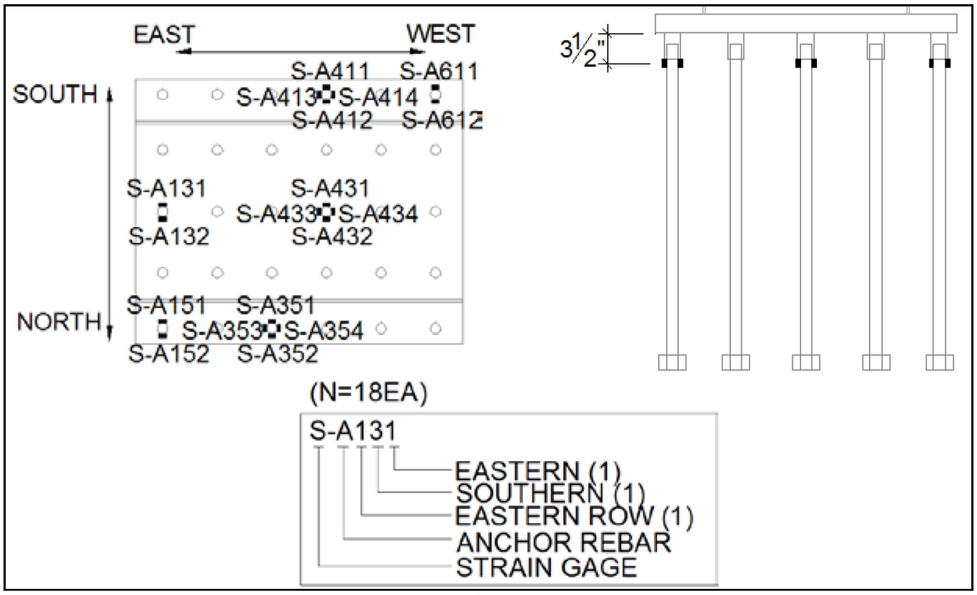
In addition, the rebar anchors themselves have also been designed per the full strength design approach, such that they too are ensured not to fail prior to the occurrence of faceplate yielding. Furthermore, the detailing of the rebar anchors and basemat reinforcement ensures that brittle failure modes would be prevented in the event that the rebar anchors were subjected to overload tensile forces. Because the anchors are ensured to fail by ductile yielding, significant force redistribution among the anchors can occur in the event of tensile overloading. This is an additional conservatism given that the rebar anchor tension is limited to the force associated with SC wall faceplate yielding.

Further justification of the approach taken to permit neglecting of any prying forces can also be obtained by considering the prying force design provisions given in the 14th Edition AISC Steel Construction Manual, Part 9, Design of Connecting Elements. These provisions are applicable to steel to steel bolted connections, such that it is conservative to apply them to baseplates founded on concrete and connected by long anchor rods which develop larger deflections than for steel to steel connections. Per Equation 9-20a, the minimum thickness required to eliminate prying action, t_{min}, is determined as

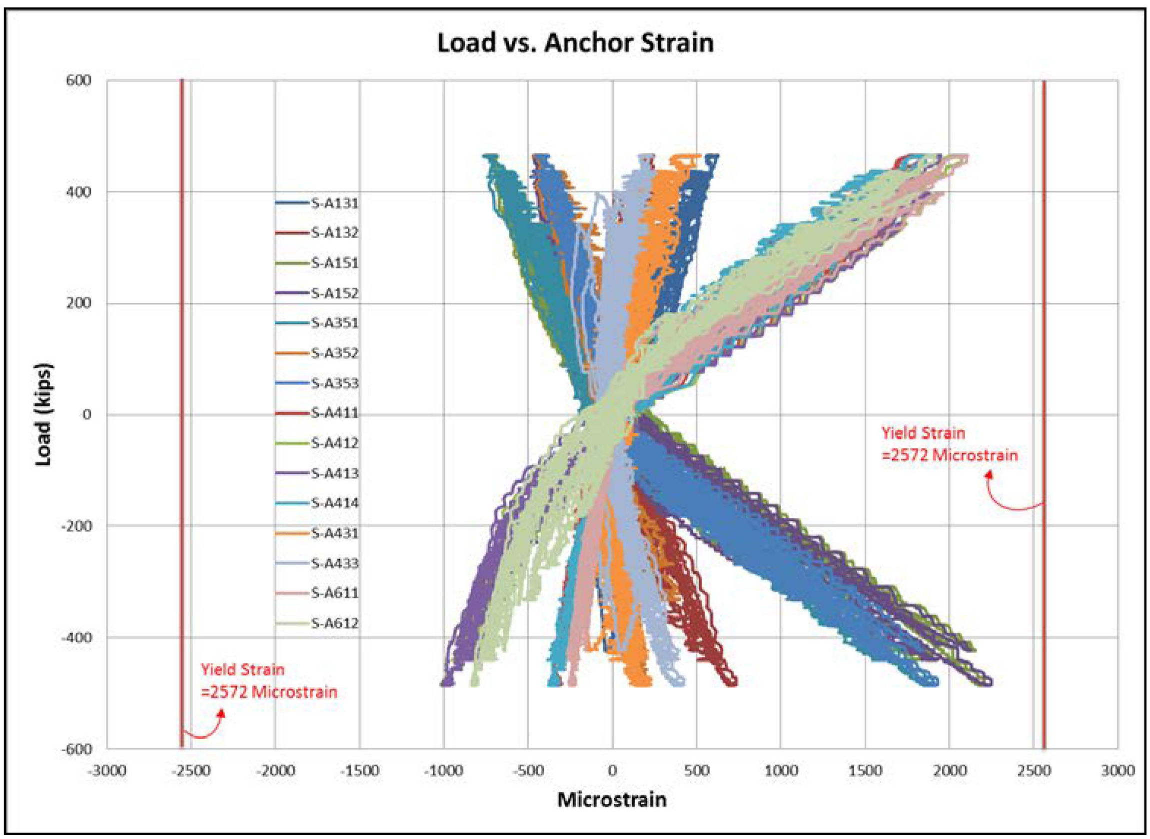
$$t_{\min} = \sqrt{\frac{4Tb'}{\phi p F_u}} = \sqrt{\frac{4 \cdot 375kip \cdot (6in - 0.25in - 2.25in/2)}{0.9 \cdot 2(6in - 0.25in) \cdot 70ksi}} = 3.09in.$$

where T is the required tensile strength ($N_r / 2$) per the full strength design procedure, b' is the arm from the face of the SC faceplate to the edge of the #18 anchor (welded rebar coupler neglected), p is the tributary length at the face of the SC faceplate, and F_u is the ultimate strength of A516 Gr. 70 steel. As shown, the thickness obtained by conservatively applying this procedure to the SC wall baseplate is less than provided (3.5 in.).

Finally, the sufficiency of the SC wall basemat anchorage design is most effectively demonstrated by the cyclic out-of-plane loading test (Series 5.2) performed in the US-APWR confirmatory testing program. As summarized in Technical Report MUAP-11013, Rev. 2, Appendix B Chapter 13, this test involved a large-scale (5:8) specimen that was detailed to be representative of the actual refueling water storage pit (RWSP) outer wall, its basemat anchorage connection, and the participating portion of the basemat. The test objective was to demonstrate the full strength connection requirements by subjecting the specimen to cyclic out-of-plane loading and confirming that the strength of the connection is governed by inelastic behavior and yielding of the SC wall, rather than failure of the anchorage. As part of this confirmation, 15 of the 30 rebar anchors in the specimen were instrumented with strain gauges, as shown in Figure 03.08.03-114-2a. The plot of the measured strains in Figure 03.08.03-114-2b shows that all of the rebar anchors remained elastic throughout the cyclic loading history and to three times the yield displacement of the SC wall. This clearly confirmed that the anchorage connection design achieves the full strength design objectives, and more specifically that the design approach used for calculating the required tensile strength of the anchors was sufficient.



(a)



(b)

Figure 03.08.03-114-2: Measurement of Anchor Strains in Series 5.2 Test

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.