RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

03/29/2013

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 340-2004 REVISION 0**
SRP SECTION:	**03.08.05 - Foundations**
APPLICATION SECTION:	**3.8.5**
DATE OF RAI ISSUE:	**04/21/2009**

QUESTION NO. 03.08.05-14:

In DCD Subsection 3.8.5.4.4, the fourth paragraph (Page 3.8-74) states, "Subsequent to the placement of the concrete foundation, walls, and containment internal structure, the basemat is significantly stiffened, minimizing any further tendency of differential settlement."

Placing concrete for walls and containment structures imposes additional loads on the concrete foundation (basemat), and may create additional settlement and differential settlement for the basemat.

The applicant is requested to:

(1) describe its analytical method used to calculate the settlement and differential settlements of the basemat with respect to the proposed construction sequences, and

(2) provide the curves of the basemat settlement vs. different stages of construction, and differential settlements of the basemat vs. different stages of construction, for the four types of soil conditions assumed in the DCD.

Use the curves/data provided in response to (2) above to substantiate the claim that "...the basemat is significantly stiffened, minimizing any further tendency of differential settlement."

ANSWER:

This answer revises and replaces the previous MHI answer that was transmitted by letter UAP-HF-09363 (ML091900557).

(1) The analytical method used to calculate the settlements and differential settlements of the Standard Plant structures is described in the answer to RAI 340-2004, Question 3.8.5-13. Additional details regarding the loads included in the settlement analysis, the method to account for time dependent deformations of soil materials, and considerations regarding the construction and the operational life of the plant are presented below.

The settlement analysis considers a generic construction schedule, as follows (Figure 1):

a) **Excavation**. This phase is assumed to be completed in Te = 6 months,

b) **Construction**. The time of construction is taken in the settlement analysis as T_C = 38 months. This represents 44 months from first concrete to fuel filling minus four months for testing (hydro-tests, shakedown, etc.) and an additional two months for major pipe connection lock-in. The reason for excluding 6 months from construction time is explained below.

c) **Operation**. The operation life of the plant is considered $T_L - T_C$ = 60.5 years, representing 40 years (standard plant commission period), plus 20 years (possible life extension), plus six months removed/eliminated from the construction time that are conservatively added to the operation time. T_L represents the total life of the plant, including construction and operation - see Figure 1.

Two categories of settlements are calculated: (1) Short term settlements, at the end of construction, and (2) long term settlements, at the end of the operational life of the plant. The deflections of interest for plant operation and especially for pipe connections are those occurring during operation. Therefore, for the purpose of this calculation, the end of construction is defined as the time when infrastructure and major equipment are in place, but before installing major pipe connections and backfilling around structures, i.e., end of construction in the settlement analysis is taken six months earlier that the actual end of construction.

The loading scenarios used for each structure along with the corresponding settlements are illustrated in Figure 1. There are different sets of loads acting during the life of the plant that contribute to short term and long term settlements:

- Dead Loads, applied during construction, and assumed to increase linearly from zero at the beginning of the construction period to their nominal value at end of construction.

- Live Loads, assumed to act with 25 percent of their maximum intensity considered for structural design (i.e., long term values), during the operational life of the plant (from end of construction to end of life.

- Weight of the backfill placed around the structures and acting during the operational life of the plant.

- Heave produced by stress reduction due to excavation that reduces settlements for clay soils (materials with large time-dependent deformations), and accounted for by calculating an equivalent reduction in loads.

Variations in groundwater, level including dewatering during construction, induce settlement variations. Based on a sensitivity study it was concluded that, for the purpose of settlement calculations, it is conservative to assume the groundwater level below the basemat elevation.

Soil behavior is nonlinear and time dependent. Subgrade settlements consist of immediate settlements that occur at load application and are elastic-plastic, and time dependent settlements that develop in time under constant load (viscous deformations, primary consolidation settlements). To capture this relatively complex behavior with a linear elastic numerical model, the soil deformation moduli used in the model are calculated as secant equivalent elastic moduli at two significant moments in the plant's life: end of construction and end of life. These secant moduli are determined in an iterative process from the condition that the average settlements of each structure at end of life and end of construction obtained from the linear analyses are approximately equal with the corresponding settlements that account for time dependent deformability and are produced after a time T_C (for the construction phase) and after a time T_L (for the entire life of the plant).

The secant moduli for end of construction and end of life are illustrated in Figure 1. They include the effects of both immediate and time dependent deformations produced up to end of construction or end of life and are calculated based on primary consolidation theory and viscous deformation analysis. The total deformations at end of construction at every location in each structure and the subgrade, δ_{EoC}, are calculated in a first three-dimensional finite element (FE) analysis using secant moduli at end of construction, E_{EoC}, and loading during the construction phase. Similarly, the total deformations at end of life at every location, δ_{EoL}, are calculated in a second three-dimensional FE analysis using secant moduli at end of life, E_{EoL}, and loading during operation phase. The deformations produced during the operation life of the plant are obtained as the difference: $\delta_{EoL} - \delta_{EoC}$.

The results are listed in Table 2.0-1 of the DCD and are provided to the COL Applicant as acceptable parameters without further evaluation (see also COL Item 3.8 (26)).

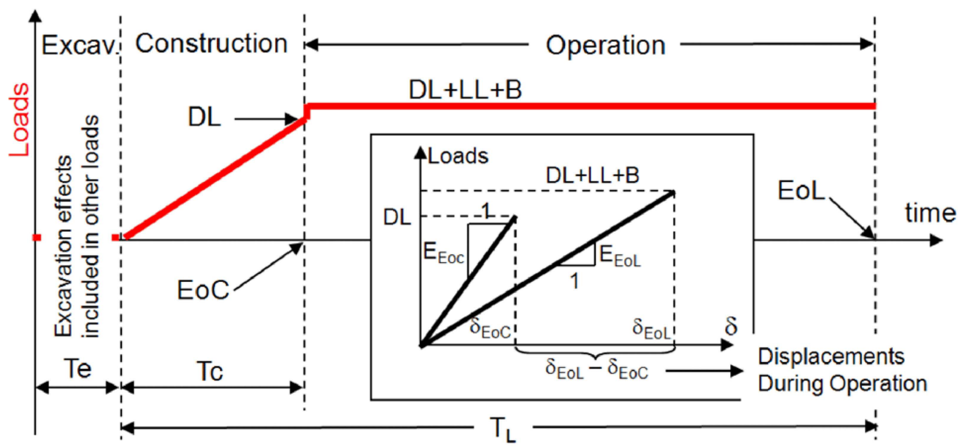

Figure 1. Loads and secant deformation moduli used in settlement analysis

(2) A detailed construction schedule is not available at this stage for the Standard Plant design. Detailed calculation of stresses developed in the basemat during construction as well as the effects of basemat stiffening on differential settlements are being currently calculated for the most deformable subgrade profile.

Curves of basemat settlements during various phases of construction cannot be provided at this stage. To answer the second part of the RAI question, the values of settlements and differential settlements calculated for the reactor building (R/B) complex at the end of construction and the end of life as discussed at (1) are listed in Table 1 for two different types of subgrade, namely predominantly sand and predominantly clay soils. Both types of subgrades correspond to the most deformable soil profile considered for the Standard Plant, namely profile 270-500 as identified in Design Control Document (DCD) Table 3.7.1-6.

Table 1. Settlements, Differential Settlements and Tilt for the R/B Complex Placed on the Most Deformable Soil Profile (270-500)

Soil type	Time	Settlement (in)	Differential Settlement (in)(*)	Maximum tilt
Predominantly Sand layers	End of Construction	3.1	2.2	1/2500
	End of Life	3.9	2.5	1/2300
Predominantly Clay layers	End of Construction	6.0	3.8	1/1500
	End of Life	8.4	5.4	1/1065

Note: (*) Differential settlement across the R/B complex basemat

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.