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Subject: AP1000 Responses to Requests for Additional Information (TR85)

Westinghouse is submitting responses to the NRC request for additional information (RAI) on AP1000 Standard Combined License Technical Report 85, APP-GW-GLR-044, "Nuclear Island Basemat and Foundation." These RAI responses are submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in the responses is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following RAIs:

RAI-TR85-SEB1-16 Rev 1
RAI-TR85-SEB1-17 Rev 1
RAI-TR85-SEB1-27 Rev 1
RAI-TR85-SEB1-28 Rev 1
RAI-TR85-SEB1-36 Rev 1
RAI-TR85-SEB1-37 Rev 1

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

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NRO

/Enclosures

1. Responses to Requests for Additional Information on Technical Report No. 85

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ENCLOSURE 1

Responses to Requests for Additional Information on Technical Report No. 85

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-16
Revision: 1

Question:

In Section 2.4.2, the third paragraph (Page 12 of 83), states that limitations on soil variability were included in the revisions to Table 2-1 in Reference 3 (TR-03) related to seismic response. However, this table does not exist. Clarification is needed.

Additional Request (Revision 1)

Since the response explains where Table 2-1 is located, the response is acceptable. However, a word "and" needs to be inserted between "this document," and "in References 3." A review of Table 2-1 reveals that one of the critical soil properties, coefficient of friction, or angle of internal friction for soils, is not included. This property should be included in Table 2-1.

Westinghouse Response:

Table 2-1 can be found in Section 5.0 of TR-85, located on pages 64-68. It can also be found in Reference 3 (TR-03) as noted in the aforementioned question. Westinghouse will add a note to the statement in TR-85 citing the location within the document.

DCD Table 2-1, Tier 2 Revision 17, has included the minimum soil angle of internal friction. Section 5 of TR-85, DCD Mark UP, does not reflect the latest DCD as presented in Revision 17. Section 5 of Technical Report 85 is being deleted from TR 85 Revision 1 as stated in the response to RAI-TR85-SEB1-017.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
Revise Section 2.4.3, third paragraph, as follows:

Limitations on soil variability were included in DCD Rev 17 Table 2-1. These limitations are also applicable to foundation design.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-17
Revision: 1

Question:

In Section 2.5, the first paragraph (Page 19 of 83) states that in the expected basemat construction sequence, concrete for the mat is placed in a single placement. The last sentence of the same paragraph states that once the shield building and auxiliary building walls are completed to Elevation 82'-6", the load path changes and loads are resisted by the basemat stiffened by the shear walls. The staff identified the following issues:

a. Since the size of the basemat is 256 feet by 161 feet, provide a detailed description of how the single placement is to be placed (e.g., by layers or by areas, time period between pouring of layers or areas, if by areas - type of joint detail to ensure proper connection, etc.).

b. Explain how the "single placement" can be completed and considered as a "single placement," if any unexpected incidents (such as malfunction of concrete mixer, etc.) occur.

c. Provide the basis of how the residual stress at the junction between the shear walls and the shield building is calculated (detailed calculation procedure needs to be provided) and designed for, if the auxiliary building shear walls are to be constructed up to Elevation 82'-6" first and then construction of the shield building.

d. Describe what construction techniques and design provisions are needed to address issues related to the use of a single massive concrete pour of the entire basemat. The response should also address concerns related to the effects of heat generation, restraint, and volume changes associated with a large single massive pour, and how the cracking of the concrete basemat will be avoided.

e. Where in the DCD is the requirement for the COL applicant to follow the construction sequences considered by Westinghouse in the design of the NI structures? If the COL applicant proposes to use a construction sequence that is substantially different than that studied by Westinghouse, the COL applicant should be required to demonstrate that their proposed sequence does not cause a problem.

Additional Request (Revision 1):

The RAI response states that the acceptability of the construction sequence used by the COL applicant is addressed by an ITAAC. However, the ITAAC could not be located; therefore, Westinghouse is requested to identify the ITAAC to be included in DCD Tier 1.

Westinghouse Response (Revision 1):

The reference to the ITAAC has been replaced in the response to item (e) by a reference to the Combined License applicant's information on settlement.

a. Site specific placement plans will be developed to address the placement of concrete for the NI basemat. Those plans will address the conditions outlined below:

   The concrete for the NI basemat will be placed in a single continuous placement operation. It is expected that the batch plant equipment and materials on site (site dependent) for this operation will consist of the following equipment or equal in order to support this placement:
   - 12 cubic yard central mix batch plant (main plant)
   - 10 or 12 cubic yard backup/auxiliary batch plant
   - All coarse and fine aggregates stockpiled on-site to support the placement
   - All admixtures (water reducer, plasticizer, air entraining agent, etc.) on-site to support the placement.
   - All cement and fly ash stored on-site (batch plant silos and supplemental storage blimps) or reliability of re-supply during the placement verified.
   - If ice is required, adequate supplies will be stored on-site or reliability of re-supply during the placement verified.
   - Adequate concrete trucks including back-up trucks on-site to support the placement.
   - Adequate personnel and truck drivers assigned to the batch plants to support multiple shift operations.

   For the main batch plant, sustained maximum production is expected to reach 250 cubic yards per hour and average production is expected to exceed 200 cubic yards per hour allowing for decreased production periods at the beginning and at the end of the concrete placement. The placement plan shall be based on the use of one plant being able to successfully complete the placement, however the back-up plant may be used during the placement. Initial plans indicate that the placement will take approximately 36 hours.

   Concrete will be placed by conventional placement equipment (i.e., pumps, conveyors, buckets, etc.) suitable for the site conditions. Telebelts (conveyors mounted on hydraulic cranes) or conventional conveyors may be used in concert with concrete pumps dependent on the site. Back-up equipment will be provided. Concrete will be placed in a "stair-step" pattern to minimize the exposed working face. Multiple concrete placing crews will be used to balance the concrete placement with the expected rate of concrete supply.

b. In theory a single placement could be interrupted for any one of several reasons. Possible causes of placement interruption based on experience at other projects are listed below together with the associated preventative or mitigating action being planned in each case for the AP1000 NI basemat.

Reason for Interruption	Preventative or Mitigating Action
Bad Weather	Placement to be made only after comprehensive site specific favorable weather forecast. Contingency plans will be in place for unexpected weather conditions.
Breakdown of Batch Plant	Back-up Batch Plant capacity on or nearby the site that satisfies Quality Control and Quality Assurance requirements of the Project. Critical system such as power supply to the batch plant will also have backup.
Breakdown of Concrete Trucks	Backup trucks will be provided.
Breakdown of Concrete Placement Equipment	Backup equipment will be provided.
Inadequate Quantities of Batch Constituents	Sufficient materials will be stored on site to provide for the required concrete quantity plus allowances for extra concrete that may be required for rejected concrete, waste and spillage and low estimated quantities.
Power Failure – unable to operate batch plant	Redundant source of power on site such as a portable diesel generator
Failure of Formwork	Field Engineers will check the formwork prior to the placement. Carpenters will be assigned to monitor the formwork during the placement.
Construction Accident	Enhanced Safety training and briefing of all supervisors and craft labor prior to the placement

In the unlikely event that a major interruption occurs in spite of the above cited Preventative or Mitigating Actions, the duration and cause of the delay and the associated effect on the integrity of the NI basemat will be evaluated. Depending on the level of the impact on the integrity, remediation actions could range from (a) removal, cleaning and green cutting of a new mating surface to (b) complete removal and subsequent placement of a portion of the placement and insertion of a new unplanned construction joint to be designed at the time of the occurrence.

c. The "residual stresses" are evaluated as "locked-in" stresses considering the immediate and long term settlements, the loading history consistent with the construction sequence, and the increasing foundation mat and superstructure stiffness as construction elements are placed and integrated into the structure.

The response to RAI-TR85-SEB1-19 presents details of the computational process and how the resulting forces and moments are considered in the design. The generic analysis includes the effects of three construction sequences, namely, a base case, a delayed Auxiliary building case and a delayed Shield building case.

d. While the quantity of concrete in the NI basemat is relatively large when compared to walls and floor slabs throughout the Nuclear Island, it is not large by normal modern construction practices. The American Concrete Institute (ACI) Code, including ACI 207.1R-05, "Guide to Mass Concrete" and ACI 207.2R-95 (reapproved 2002) "Effect of Restraint, Volume Change and Reinforcement on Cracking of Mass Concrete," has been considered in the design and planning of the NI basemat placement. The most significant issue is the heat of hydration associated with large placement which, in theory, could lead to deleterious cracking if not addressed in the design and construction operation. Depending on the site location and conditions, the concrete temperature will be monitored and the concrete mix will be designed to minimize the heat of hydration, associated temperature rise and subsequent drop and the related tendency for cracking. Measures available for dealing with the heat of hydration, to be worked out on a site by site basis depending on the time of the year and location of the site, include the following:

Aggregate Size and cement fineness
Overall placement procedure
Use of chilled water and/or ice
Enhanced quantity of flyash (pozzolanic)
Use of chilled aggregate
Immediate commencement of curing after finishing
Use of misting equipment
Additives such as water reducers & retarders
Evaporative cooling (water spray) of aggregates

e. DCD 3.8.5.4.2 describes three construction sequences that were evaluated for a soft soil site to demonstrate construction flexibility within broad limits. The acceptability of the construction sequence used by the COL applicant is addressed by the settlement analyses described in DCD subsection 2.5.6.4 which provides guidance to the Combined License applicant on predictions of absolute and differential settlement that are acceptable without further evaluation. When the predicted settlement exceeds these values, the Combined License applicant will describe any special construction provisions to accommodate the predicted settlement.

- A base construction sequence which assumes no unscheduled delays.

- A delayed shield building case which assumes a delay in the placement of concrete in the shield building while construction continues in the auxiliary building.
- A delayed auxiliary building case which assumes a delay in the construction of the auxiliary building while concrete placement for the shield building continues.

The analyses of alternate construction scenarios show that member forces in the basemat are acceptable subject to the following limits imposed for soft soil sites on the relative level of construction of the buildings prior to completion of both buildings at elevation 82′ -6″:

- Concrete may not be placed above elevation 84′ -0″ for the shield building or containment internal structure.
- Concrete may not be placed above elevation 117′ -6″ in the auxiliary building, except in the CA20 structural module where it may be placed to elevation 135' - 3".

References:

ACI 207.1R-05, "Guide to Mass Concrete"
ACI 207.2R-95 (Re-approved 2002), "Effect of Restraint, Volume Change and Reinforcement on Cracking of Mass Concrete"

Design Control Document (DCD) Revision:

The revisions described in Revision 0 of this response are incorporated in DCD Rev 17. No additional changes are required.

PRA Revision:

None

Technical Report (TR) Revision:

Delete Section 5, DCD markup from the Technical Report.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-27
Revision: 1

Question:

Section 2.6.1.4 discusses liftoff analyses performed for 16 load cases of dead, live, and seismic loads. The results of the analyses are used for the basemat design. Explain what the 16 load cases correspond to and why weren't all possible load combinations utilized in accordance with the 100/40/40 rule.

Additional Request (Revision 1):

The response explains that the non-linear analyses were not performed for the cases with 1.0 applied in the vertical direction since the maximum bearing demand is due to overturning rather than vertical seismic. It is not evident that this would always be the case. Please explain.

The purpose of the calculation described in Section 2.6 is not to find the maximum bearing pressure under the basemat, but rather to design the entire basemat. Explain your confidence that at other locations away from the maximum bearing pressure location, the combination with 1.0 applied to the vertical direction may not govern (e.g., near the line of rotation where overturning contribution would be very small). The applicant is requested to consider the 100/40/40 combination method for considering the three earthquake directions as it was intended, and not to drop certain combinations based on a judgment that has not been justified.

Westinghouse Response:

Linear analyses were performed for all 24 cases of the 100/40/40 combination method in the initial hard rock analyses and used to select the 16 cases analyzed in subsequent non-linear analyses. Typical results are shown in Figure RAI-TR85-SEB1-027-01. The cases with unit load factor in the vertical direction are load cases 17 to 24. The following 16 cases for the 1.0, 0.4, 0.4 method were used. Non-linear analyses were not performed for the cases with 1.0 applied in the vertical direction since the maximum bearing and member force demand is due to overturning rather than vertical seismic.

Load Case 3-# = D+L+Es where Es takes the following forms for each #.

#=1:	Es= 1.0xSns	+0.4xSew	+0.4xSvt
#=2:	Es= 1.0xSns	+0.4xSew	-0.4xSvt
#=3:	Es= 1.0xSns	-0.4xSew	+0.4xSvt
#=4:	Es= 1.0xSns	-0.4xSew	-0.4xSvt
#=5:	Es= -1.0xSns	+0.4xSew	+0.4xSvt
#=6:	Es= -1.0xSns	+0.4xSew	-0.4xSvt
#=7:	Es= -1.0xSns	-0.4xSew	+0.4xSvt

#=8:	Es= -1.0xSns	-0.4xSew	-0.4xSvt
#=9:	Es= 0.4xSns	+1.0xSew	+0.4xSvt
#=10:	Es= 0.4xSns	+1.0xSew	-0.4xSvt
#=11	Es= 0.4xSns	-1.0xSew	+0.4xSvt
#=12	Es= 0.4xSns	-1.0xSew	-0.4xSvt
#=13:	Es= -0.4xSns	+1.0xSew	+0.4xSvt
#=14:	Es= -0.4xSns	+1.0xSew	-0.4xSvt
#=15:	Es= -0.4xSns	-1.0xSew	+0.4xSvt
#=16:	Es= -0.4xSns	-1.0xSew	-0.4xSvt

where,

Sns element forces due to SSE acceleration in X (NS)
Sew element forces due to SSE acceleration in Y (EW)
Svt element forces due to SSE acceleration in Z (VT)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:

Revise section 2.6.1.4 as follows: The underlined portion is added by Revision 1 of this response.

2.6.1.4 Normal plus seismic reactions

Liftoff analyses were performed for 16 load cases of dead, live and seismic loads for the soil site with subgrade modulus of 520 kcf. Seismic loads are applied with unit factor in one direction and with 0.4 factor in the other two directions. The 16 cases were those having the unit factor applied in the horizontal direction in order to maximize the overturning. Cases with unit factor in the vertical direction <u>were also analyzed in linear analyses and</u> do not control. Maximum bearing reactions at the corners of the auxiliary building and at the west side of the shield building are shown in Table 2.6-3. Bearing pressure contours are shown in Figures 2.6-4 to 2.6-8 for the five load cases resulting in these maximum bearing reactions. The seismic load combination is shown for each figure. Note that the bearing pressures reduce rapidly away from the corners. These figures show lift off for equivalent static loads which are higher than the maximum time history loads as discussed in section 2.4.2. This is particularly the case for load combinations with unit seismic load in the Y direction (East-West) where the footprint dimension is smaller. The results of the equivalent static analyses are used for basemat design. The maximum bearing capacity reactions for defining minimum dynamic soil bearing capacity are based on time history analyses as discussed in Section 2.4.2.

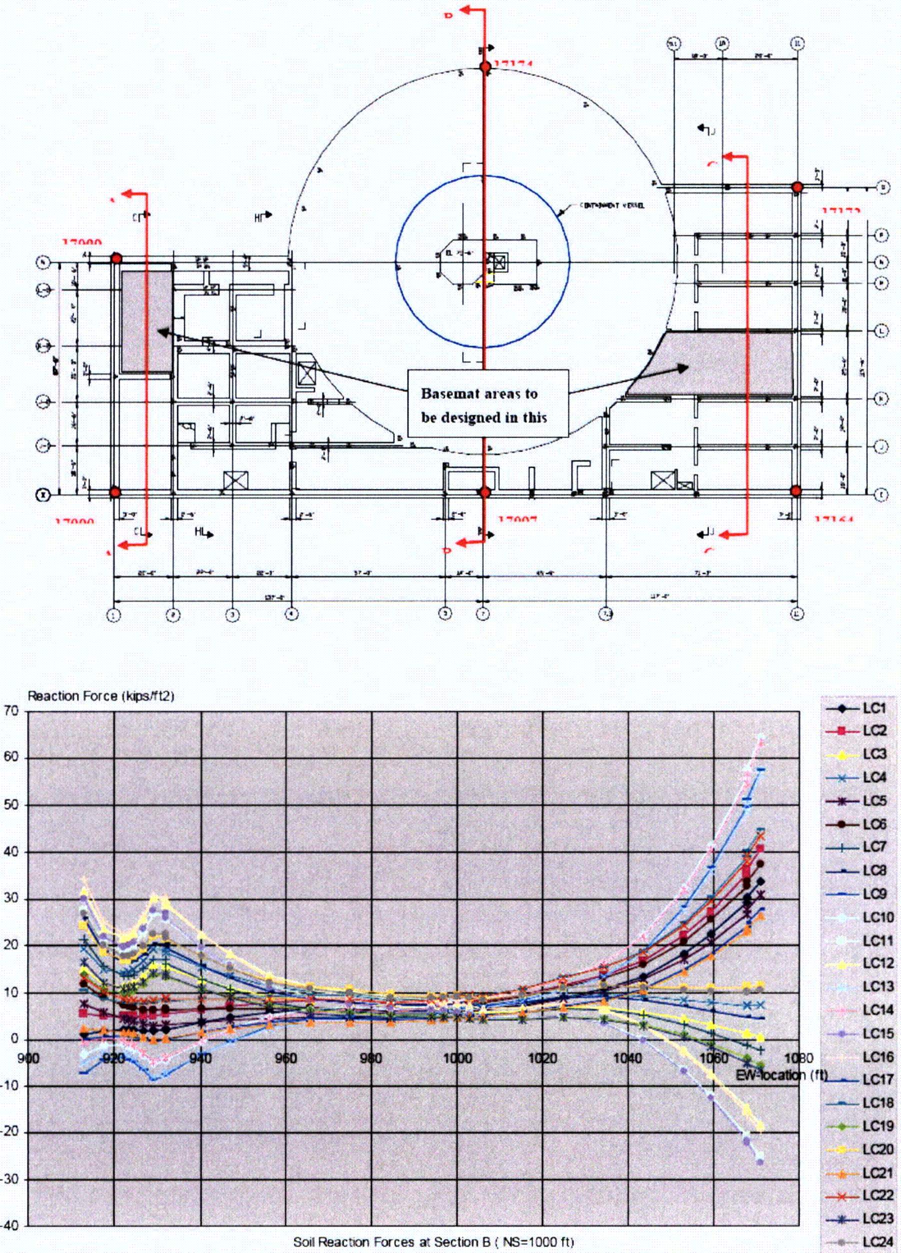

Figure RAI-TR85-SEB1-027-01 Soil Reaction Forces on Section B-B

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-36
Revision: 1

Question:

Section 5.1 presents the proposed revisions to DCD Tier 2, Table 2-1, which contains the Site Parameters including those for the soil media. Section 5.2 presents the proposed revisions to DCD Tier 1, Table 5.0-1, which also contains the Site Parameters for the soil. Considering that now the foundation of the AP1000 design has been extended to soil sites, both tables should include the additional items listed below or justification provided for not including the items.

a) Minimum required soil friction angle for soils below and adjacent to the NI. A minimum value of 35 degrees was used in the foundation stability calculations.

b) Settlement Criteria - maximum settlement at key locations (e.g., the corners of the basemat and west side of the shield building), maximum average settlement considering these key locations, maximum differential displacement (e.g., between key locations), and maximum differential displacement between any adjacent structures. Considering the relatively thin 6'-0" basemat for the NI, this criteria is considered important to ensure that there will not be significant settlement which might compromise the structural integrity of the NI basemat and foundation. Also, meeting differential settlement criteria would maintain adequate gap with adjacent structures under seismic loadings to preclude impact. The approach or basis for the selected settlement values should be described.

Additional Request (Revision 1):

The proposed revision to the DCD does not clearly state what is required regarding the evaluation for settlement. As an example, Sections 2.5.4.3 and 2.5.4.6.11 state that "Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values in Table 2.5-1." Therefore, Westinghouse is requested to explain whether the intent of the settlement criteria in the proposed revision to the DCD is to require that the Combined License applicant calculate predicted settlements before construction activities begin. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period. These predicted displacements would then be compared to the proposed acceptable settlement values (considered in design), which are presented in Table 2.5-1 of the RAI response. If the predicted displacements exceed the limits of acceptable settlement, then a detailed evaluation and plan needs to be developed before proceeding with the construction. As construction begins, actual measured settlements would then be compared to the predicted settlement values and if exceeded, then a detailed evaluation and plan needs to be developed before proceeding with the construction. If this is the intent of the DCD settlement criteria, then revise DCD Tier 2, Section 2.5.4 including Section 2.5.4.6 - Combined License Information, and DCD Tier 1, Section 5 - Site Parameters to clearly describe the settlement criteria requirements in terms of the items discussed above. Otherwise, provide the technical basis for not doing so.

Westinghouse Response:

a) The minimum required soil friction angle has been added to both Tables 2-1 and 5.0-1 in accordance with Westinghouse's response to RAI-TR-SEB1-37.

b) DCD subsection 2.5.4.6.11 requires the Combined License applicant to evaluate settlement at soil sites. These evaluations may be performed assuming rigid basemat behavior of the nuclear island and the adjacent buildings.

The effect of settlement on the nuclear island basemat during construction has been considered in the design of the nuclear island as described in Section 2.5 of the report and in DCD subsection 3.8.5.4.2. These analyses consider the flexibility of the basemat during construction. They consider a soft soil site with properties selected to maximize the settlement during construction. These analyses show total settlements of about one foot. The analyses demonstrate that even this significant settlement does not compromise the structural integrity of the NI basemat and foundation.

Westinghouse has established guidance on settlement for the Combined License applicant shown in Table TR85-SEB1-36-1. If site specific settlement analyses predict settlement below the values in this table, the site is acceptable without additional evaluation. If the analyses predict greater settlement, additional evaluation will be performed. This may include specification of the initial building elevations, specification of the stage of construction and settlement for making connections of systems between buildings, etc. It would also include review of the effect of the rotation of buildings and its effect on the gap between adjacent structures. These analyses would provide the basis for review of settlement measurements during construction and subsequent operation.

Acceptable differential settlement between buildings without additional evaluation is identified as 3 inches between the Nuclear Island and the Turbine Building, the Annex Building, and the Radwaste Building. The 3 inches is measured from the center of the Containment Building to the center of the Turbine Building, center of the Annex Building, or the center of the Radwaste Building. Each building, including the Nuclear Island, also has a settlement criterion of no more than ½ inch in 50 feet in any direction. The Nuclear Island has a maximum absolute settlement value of 3 inches.

TABLE TR85-SEB1-36-1
Limits of Acceptable Settlement Without Additional Evaluation

Differential Across Nuclear Island Foundation Mat	Total for Nuclear Island Foundation Mat	Differential between Nuclear Island and Turbine Building.	Differential between Nuclear Island and Other Buildings
½ inch 50 ft	3 inches	3½ inch	3½ inch

Westinghouse Response to Revision 1:

The intent of the settlement criteria in the proposed revision to the DCD is to require that the Combined License applicant calculate predicted settlements and provide them in the Combined License application. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period. The predicted settlements will be based on conservative assumptions of soil properties. The predicted settlements would be compared to the settlement values in Table 2.5-1 of the DCD that are considered acceptable without further evaluation. If the predicted settlements exceed the limits of acceptable settlement, a detailed evaluation and plan will be described by the Combined License applicant before proceeding with the construction. As construction begins at a soil site, actual measured settlements would then be compared to the predicted settlement values and any exceedances would require additional investigation before proceeding with the construction.

A revision is shown below to DCD Tier 2, Section 2.5.4 including Section 2.5.4.6 - Combined License Information to clearly describe the settlement criteria requirements in terms of the items discussed above. This is Tier 2 information and does not require a revision to the DCD Tier 1, Section 5 - Site Parameters

References: None

Design Control Document (DCD) Revision:

The revisions to the DCD identified in Revision 0 of this response have been incorporated in DCD Revision 17. The following revisions are to DCD Rev 17.

Revise subsections 2.5.4.3 and 2.5.4.6.11 as follows:

2.5.4.3 Settlement

The Combined License applicant will address short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the nuclear island foundation and adjacent buildings consistent with the construction sequence. The resulting time-history of settlements includes construction activities such as dewatering, excavation, bearing surface preparation, placement of the basemat, and construction of the superstructure.

The AP1000 does not rely on structures, systems, or components located outside the nuclear island to provide safety-related functions. Differential settlement between the nuclear island foundation and the foundations of adjacent buildings does not have an adverse effect on the safety-related functions of structures, systems, and components. Differential settlement under the nuclear island foundation could cause the basemat and buildings to tilt. Much of this settlement occurs during civil construction prior to final installation of the equipment. Differential settlement of a few inches across the width of the nuclear island would not have an adverse effect on the safety-related functions of structures, systems, and components. Table 2.5-1 provides guidance to the Combined License applicant on predictions of absolute and differential settlement that are acceptable without further evaluation. The predicted settlements will cover the periods before construction begins through the construction phase, and for the subsequent plant operating period. The predicted settlements will be based on conservative assumptions of soil properties. If the predicted settlements exceed the limits of Table 2.5-1, a detailed evaluation and construction plan will be described by the Combined License applicant. During construction at a soil site, settlements would be measured and compared to the predicted settlement values and any exceedances would require additional investigation. ~~When the predicted settlement exceeds these values, the Combined License applicant will describe any special construction provisions to accommodate the predicted settlement.~~

2.5.4.6.11 Settlement of Nuclear Island – Data will be provided on short-term (elastic) and long-term (heave and consolidation) settlement for soil sites for the history of loads imposed on the nuclear island foundation and adjacent buildings consistent with the construction sequence. The resulting time-history of settlements includes construction activities such as dewatering, excavation, bearing surface preparation, placement of the basemat, and construction of the superstructure. Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values shown in Table 2.5-1.

Revise Table 2-5-1 to be consistent with the 3 inch deflection described in the text.

Table 2.5-1

LIMITS OF ACCEPTABLE SETTLEMENT WITHOUT ADDITIONAL EVALUATION

Differential Across Nuclear Island Foundation Mat	Total for Nuclear Island Foundation Mat	Differential Between Nuclear Island and Turbine Building	Differential Between Nuclear Island and Other Buildings
1/2 inch 50 ft	3 inches	3~~1/2~~ inch	3~~1/2~~ inch

PRA Revision:

None

Technical Report (TR) Revision:

None

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-37
Revision: 1

Question:

In Section 5.1, entitled "Proposed Revisions to DCD Section 2.5," the DCD mark up of Section 2.5.4.6.2 states that "Seismic stability requirements are satisfied if the soil layers below and adjacent to the nuclear island foundation are composed predominantly of rock or sand and rock (gravel), or sands that can be classified as medium to dense (standard penetration test having greater than 10 blows per foot)." This criterion of 10 blows per foot, places the soil at the boundary of loose to medium and not medium to dense soils. Also, using the criteria of 10 blows per foot places the soil friction angle below the minimum required 35 degrees for the NI stability calculations. Therefore, provide the technical justification for the adequacy of the blow count criteria and demonstrate that it is consistent with the minimum soil friction angle of 35 degrees used in design and stability calculations. The soil friction angle should also be specified separately as a site interface criteria for soil in DCD Table 2-1 and in DCD Tier 1.

Additional Request (Rev. 1)

The RAI response indicates that the phrase "medium to dense" will be revised to read "medium or dense" when describing the sands for which the stability requirements were satisfied. This change addresses the first part of the original RAI. However, this change does not address the second part of the RAI which indicates that using the criterion of 10 blows per foot for medium or dense sands, places the soil friction angle below the minimum required 35 degrees for the nuclear island stability evaluations. Therefore, Westinghouse is requested to revise the blow count criteria or to provide the technical justification for the adequacy of the 10 blows per foot criteria and demonstrate that it is consistent with the minimum soil friction angle of 35 degrees used in the design and stability calculations.

Westinghouse Response:

References 1 and 2 provide the technical justification linking the SPT blow count to the internal angle of friction. Table RAI-TR85-SEB1-37-1 (shown below) provides the illustration that a Medium sand with a SPT blow count of 10-30 blows/ft is consistent with an internal angle of friction ranging from 32 to 36 degrees. The NRC is correct that the blow count of greater than 10 places the soil on the boundary of loose to medium. The description "medium to dense" was not intended to define the minimum but rather to state the sands for which the stability requirements were satisfied. The DCD will be clarified to read "medium or dense".

The soil friction angle will be specified separately as a site interface criterion for soil in DCD Table 2-1 and in DCD Tier 1. However, this is limited to soils below the nuclear island. Where side soils do not satisfy the internal friction angle of 35 degrees, DCD subsection 2.2.5.4.6.2 requires the Combined License applicant to evaluate the seismic stability against sliding as described in subsection 3.8.5.5.3 using the site-specific soil properties. In many cases, such as cases where groundwater is significantly below grade, seismic stability can be demonstrated without taking credit for the resistance of the side soils.

Table RAI-TR85-SEB1-37-1 – Soil Properties

Soil Types	Standard Penetration Test N - Blows/ft	Angle of Internal Friction Φ - degrees
Sands (1)	[Ref. 1, Table 10, page 294]	[Ref. 2, Section 5, Table 2] (2)
Very Dense	> 50	41° to 46°
Dense	30-50	36° to 41°
Medium	10-30	32° to 36°
Loose	4-10	28.5° to 32°
Very Loose	0-4	< 28.5°

Notes to Table RAI-TR85-SEB1-37-1:

(1) As stated in Reference 2 "for dry silts and very silty sands values of Φ are usually 2 to 6 deg. less than those shown in Table 2." The Table 2 values are those given in this table for dry sand composed primarily for quartz. Also it is stated in Reference 2, "for silts and very silty sands below the groundwater table, values of Φ are, for the great majority of cases, considerably less (one-third to one-half) than the values for dry material." Reference 1, page 86, states that angle of friction values for silt and silty sand "obtained from slow-shear tests range from about 27° to 30° for the loose state, and 30° to 35° for the dense state. These values are almost as great as those for sand."

(2) Using Table 7, page 82 of Reference 1, a description of the soil can be obtained based on the angle of friction. For the loose sand as well as the combined category of dense/very dense sand, the sand with an angle of friction in the lower range, the sand is made up of uniform round grains, for the upper range it has angular grains that are well graded.

Westinghouse Response (Revision 1):

A change to the DCD in the second paragraph of subsection 2.5.4.6.2 will be made to indicate that for medium sand a blow count greater than 10 blows per foot, or for dense sand a blow count greater than 30 blows per foot is representative of acceptable backfill. The standard penetration test having greater than 10 blows per foot provides the means of assuring that the side soil is competent. There has been no requirement placed on the applicant that the backfill adjacent to the Nuclear Island walls below grade must have a friction angle of 35° or greater. However, it is anticipated that the friction angle will be above 32° for the side soil backfill based on Table RAI-TR85-SEB1-37-1. Recognizing that not all of the passive pressure is required, as discussed in RAI-TR85-SEB1-34, 35, and 40, the sand backfill that ranges from medium to very dense, as well as sand and gravel, and rock provide adequate passive pressures as seen in Table RAI-TR85-SEB1-37-2, noting that Case 15 is used for the AP1000 design. Further, it is noted in the DCD that the COL applicant must do the following:

- Per Subsection 2.5.4.6.2, Revision 17, "If the soil below and adjacent to the exterior walls is made up of clay, sand and clay, or other types of soil other than those classified above as competent, then the Combined License applicant will evaluate the seismic stability against sliding as described in subsection 3.8.5.5.3 using the site-specific soil properties."

- Per Subsection 2.5.4.6.7, Revision 17, "Earth Pressures – The Combined License applicant will describe the design for static and dynamic lateral earth pressures and hydrostatic groundwater pressures acting on plant safety-related facilities using soil parameters as evaluated in previous subsections."

- Per Subsection 2.5.4.6.9, Revision 17, "Static and Dynamic Stability of Facilities – Soil characteristics affecting the stability of the nuclear island will be addressed including foundation rebound, settlement, and differential settlement."

- Per Table 2-1 (Tier 2) and Table 5.0-1 (Tier 1), Revision 17, the minimum soil angle of internal friction must be greater than or equal to 35 degrees below the footprint of the Nuclear Island at its excavation depth.

With these COL required actions, it can be further verified that the backfill is competent and have adequate passive pressure to meet the seismic stability requirements.

Table RAI-TR85-SEB1-37-2 – Passive Pressure, El. 60' 6"

Type of Soil		Case	γ_{sub} #/ft^3	γ_{sat} #/ft^3	ϕ deg	P_P psf
Rock	Hard Rock	1	115	175	46	28563
	Rock	2	100	160	46	24933
	Soft Rock	3	100	160	52	34328
	Soft Rock	4	100	160	43	21527
	Soft Rock	5	85	145	52	29331
	Soft Rock	6	85	145	43	18393
Sand & Gravel		7	80	140	36	12634
		8	80	140	32	10675
Sands	Very Dense	9	100	160	46	24933
		10	100	160	41	19597
		11	70	130	46	17674
		12	70	130	41	13891
	Dense	13	88	150	41	17334
		14	88	150	36	13867
		15	87.6	150	35	13229
		16	65	110	36	10236
		17	65	110	36	10236
	Medium	18	68	130	36	10824
		19	68	130	32	9145
		20	60	95	36	9398
		21	60	95	32	7941

References:

1. Terzaghi, Karl, and Ralph B. Peck, Soil Mechanics in Engineering Practice, John Wiley & Sons, Inc., New York, 1948.

2. Gaylord, E.H., et. al., ed, Structural Engineering Handbook, 4th ed, McGraw-Hill, 1997.

Design Control Document (DCD) Revision:

Revisions identified in Revision 0 of this response have been incorporated in DC Rev 17. In the third paragraph of subsection 2.5.4.6.2 of Revision 17 the change indicated below will be made:

> Properties of Materials Adjacent to Nuclear Island Exterior Walls – A determination of the static and dynamic engineering properties of the surrounding soil will be made to demonstrate they are competent and provide passive earth pressures greater than or equal to those used in the seismic stability evaluation for sliding of the nuclear island. Seismic stability requirements are satisfied if the soil layers below and adjacent to the nuclear island foundation are composed predominantly of rock, or sand and rock (gravel), or sands that can be classified as medium (standard penetration test having greater than 10 blows per foot) or dense (standard penetration test having greater than 30 blows per foot). If the soil below and adjacent to the exterior walls is made up of clay, sand and clay, or other types of soil other than those classified above as competent, then the Combined License applicant will evaluate the seismic stability against sliding as described in subsection 3.8.5.5.3 using the site-specific soil properties.

PRA Revision:
None

Technical Report (TR) Revision:

Section 5 of Technical Report 85 is being deleted from TR 85 Revision 1 as stated in the response to RAI-TR85-SEB1-017.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-28
Revision: 1

Question:

Section 2.6.2 states the following, "These load combinations are selected from the load combinations in Table 3.8.4-2 of the DCD." The load combinations presented in the Technical Report do not appear to be consistent with those in Table 3.8.4-2 of the DCD. Also, provide the technical basis for excluding some of the other load combinations (e.g., those with Wind, P_a, $P_a + T_a + E_s$).

Additional Request (Revision 1):

The staff reviewed the RAI response provided in Westinghouse letter dated 10/19/07. The load combinations presented in Section 2.6.2 of the TR are not consistent with Table 3 of the RAI response nor with DCD Section 3.8.5.3, which refers to the load combinations in DCD Section 3.8.4.3 (which in turn refers to DCD Table 3.8.4-2). As an example, Section 2.6.2 of the TR identifies load combination 1 as 1.4 x (D + H) + 1.7 x (L). However, Table 3 of the RAI response and DCD Table 3.8.4-2 specify 1.4 x (D + F) + 1.7 x (L + H) + R_o. Also, load combination number 10 is identified in the TR; however, DCD Table 3.8.4-2 does not contain this load combination. Westinghouse is requested to respond to the original RAI and demonstrate how all of the listed load combinations in Section 2.6.2 of the TR are consistent with those in DCD Section 3.8.5.3, 3.8.4.3, and Table 3.8.4-2.

The RAI response adequately addresses the elimination of the load combinations with wind or tornado; however, it does not address adequately the basis for elimination of all the other load combinations. (e.g., those associated with other loads such as containment accident pressure using containment design pressure and associated thermal loads, earth pressure, and liquid, in combination with and without seismic loads). Therefore, all of the other loads need to be considered, unless otherwise justified.

Westinghouse Response:

The load combination numbers in Section 2.6.2 are those from Table 3 of the Civil Design Criteria which is shown on the ~~next~~ last page. These load combinations are consistent with DCD subsection 3.8.5.3 as shown below, except that the load factor on containment design pressure is specified as 1.5 instead of 1.4:

> *Loads and load combinations are described in subsection 3.8.4.3. As described in subsection 3.8.2.1.2, the bottom head of the steel containment vessel is the same as the upper head and is capable of resisting the containment internal pressure without benefit of the nuclear island basemat. However, containment pressure loads affect the nuclear island basemat since the concrete is stiffer than the steel head. The containment design pressure is included in the*

design of the nuclear island basemat as an accident pressure in load combinations 5, 6, and 7 of Table 3.8.4-2.

Wind and tornado loads are not analyzed because they are substantially lower than those for SSE as demonstrated by the safety factors on stability shown in DCD Table 3.8.5-2. There are no pipe ruptures (P_a ,T_a) that would affect the nuclear island basemat.

Westinghouse Response (Revision 1):

The load combinations in DCD Table 3.8.4.2 and in Table 3 of the Civil Design Criteria were compared. The differences do not affect the design. For consistency, the DCD Table 3.8.4.2 will be revised as follows:

- Earth pressure will be included in Load Combination 6
- New DCD Load Combinations (10, 11) will be added applicable to the design of the nuclear island basemat. These load combinations are described in the text of subsection 3.8.5 but were not included in the table. These load combinations include the containment design pressure of 59 psig.

Note that the load combinations in the DCD will then be identical to those in the Civil Design Criteria except for the load combination numbering; DCD Load Combinations 6 to 11 will be Load Combinations 5a, 6 to 10 in the Civil Design Criteria. DCD Load Combination 6 was added during the NRC Staff review of the AP600 and was inserted as 5a to avoid changing the numbering of other load combinations already included in the design criteria and calculations.

Section 2.6.2 of the TR incorrectly identified the load factor on the earth pressure (H) in load combination 1 as 1.4. This was confirmed by review of the design calculations. Section 2.6.2 of the TR will be corrected.

The loads included in the analysis are based on consideration of all specified loads. Earth pressures are included. There are no liquid pressures. Containment design pressure is considered in load combinations 10 and 11 and bounds any accident scenario. There are no pipe ruptures (P_a ,T_a) that would affect the nuclear island basemat. There are no significant thermal gradients across the basemat and any accident thermal would be slow in developing and would not be concurrent with containment design pressure. There is no major equipment on the basemat. Equipment reactions are considered in design of anchor bolts and embedments and do not affect the overall design of the basemat.

Design Control Document (DCD) Revision:

Revisions identified in Revision 0 of this response have been incorporated in DC Rev 17. The following revisions are relative to DCD Rev 17. Revise Table 3.8.4-2 as shown on page 4 and 5.

PRA Revision:
None

Technical Report (TR) Revision:

Revise second paragraph of Section 2.6.2 as follows:

The reinforcement required is calculated for the member forces for each of the following load combinations. These load combinations are selected from the load combinations in Table 3.8.4-2 of the DCD (Reference 1). Other load combinations do not control design of the basemat.

1	1.4 x (D) + 1.7 x (H) + 1.7 x (L)	
3	D + L + H + Es	
9	1.4 x (D) + 1.7 x (H) + 1.7 x (L) + 1.5 x (Pd)	(DCD LC 10)
10	D + L + H + Pd + Es	(DCD LC 11)

Table 3.8.4-2

*[LOAD COMBINATIONS AND LOAD FACTORS FOR SEISMIC CATEGORY I CONCRETE STRUCTURES]**

		Load Combination and Factors										
Combination No.		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Dead	D	*1.4*	*1.4*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.05*	*1.05*	*1.4*	*1.0*
Liquid	F	*1.4*	*1.4*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.05*	*1.05*	*1.4*	*1.0*
Live	L	*1.7*	*1.7*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.3*	*1.3*	*1.7*	*1.0*
Earth	H	*1.7*	*1.7*	*1.0*	*1.0*	*1.0*	*1.0*	*1.0*	*1.3*	*1.3*	*1.7*	*1.0*
Design Pressure	P_d										*1.5*	*1.0*
Normal reaction	R_o	*1.7*	*1.7*	*1.0*	*1.0*				*1.3*	*1.3*	*1.7*	*1.0*
Normal thermal	T_o			*1.0*	*1.0*				*1.2*	*1.2*		
Wind	W		*1.7*							*1.3*		
Safe shutdown earthquake	E_s			*1.0*				*1.0*				*1.0*
Tornado	W_t				*1.0*							
Accident pressure	P_a					*1.4*	*1.25*	*1.0*				
Accident thermal	T_a					*1.0*	*1.0*	*1.0*				
Accident thermal reactions	R_a					*1.0*	*1.0*	*1.0*				
Accident pipe reactions	Y_r						*1.0*	*1.0*				
Jet impingement	Y_j						*1.0*	*1.0*				
Pipe impact	Y_m						*1.0*	*1.0*				

__Notes:__

1. *Design for mechanical loads is in accordance with ACI-349 Strength Design Method for all load combinations. Design for combinations including thermal loads is described in subsection 3.8.3.5.3.4.*
2. *Where any load reduces the effects of other loads, the corresponding coefficient for that load is taken as 0.9 if it can be demonstrated that the load is always present or occurs simultaneously with the other loads. Otherwise the coefficient for the load is taken as zero.*

3. *Loads due to maximum precipitation are evaluated using load combination 4 with the maximum precipitation in place of the tornado load.*
4. *Load combinations 10 and 11 are applicable to nuclear island basemat design only. Pd, the containment design pressure, is 59 psig.*

WESTINGHOUSE PROPRIETARY CLASS 2
AP1000 CIVIL/STRUCTURAL DESIGN CRITERIA

TABLE 3
LOAD COMBINATIONS AND LOAD FACTORS FOR CATEGORY I CONCRETE STRUCTURES

Load Combinations and Factors

Combination #		1	2	3	4	5	5A	6	7	8	9[3]	10[3]
Load Description												
Dead	D	1.4	1.4	1.0	1.0	1.0	1.0	1.0	1.05	1.05	1.4	1.0
Liquid	F	1.4	1.4	1.0	1.0	1.0	1.0	1.0	1.05	1.05	1.4	1.0
Live	L	1.7	1.7	1.0	1.0	1.0	1.0	1.0	1.3	1.3	1.7	1.0
Earth	H	1.7	1.7	1.0	1.0	1.0	1.0	1.0	1.3	1.3	1.7	1.0
Design Pressure	P_d										1.5	1.0
Normal reaction	R_o	1.7	1.7	1.0	1.0				1.3	1.3		
Normal thermal	T_o			1.0	1.0				1.2	1.2		
Wind	W		1.7							1.3		
SSE	E_s			1.0				1.0				1.0
Tornado	W_t				1.0							
Accident pressure	P_a					1.4	1.25	1.0				
Accident thermal	T_a					1.0	1.0	1.0				
Accident thermal reactions	R_a					1.0	1.0	1.0				
Accident pipe reactions	Y_r						1.0	1.0				
Jet impingement	Y_j						1.0	1.0				
Pipe Impact	Y_m						1.0	1.0				

Notes:
1) Design per ACI-349 Strength Design Method for all load combinations
2) Where any load reduces the effects of other loads, the corresponding coefficient for that load shall be taken as 0.9 if it can be demonstrated that the load is always present or occurs simultaneously with the other loads. Otherwise the coefficient for the load shall be taken as zero.
3) Load combinations 9 and 10 are applicable to nuclear island basemat design only. P_d, the containment design pressure, is 59 psig.