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Subject: AP1000 Response to Request for Additional Information (TR 85)

Westinghouse is submitting responses to NRC requests for additional information (RAI) on Technical Report No. 85. This RAI response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response 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 RAI(s):

RAI-TR85-SEB1-17 R4
RAI-TR85-SEB1-32 R3

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
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/Enclosure

1. Response to Request for Additional Information on Technical Report No. 85

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NRO

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ENCLOSURE 1

Response to Request for Additional Information on Technical Report No. 85

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-17
Revision: 4

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.

Additional Request (Revision 2):

The staff reviewed the RAI response provided in Westinghouse letter dated 12/2/08. The staff concurs that DCD Rev. 17 Section 3.8.5.4.2 has been revised to update the information for the three construction sequences that were evaluated to demonstrate construction flexibility within certain limits. However, a statement in the RAI response indicates that 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. Since DCD subsection 2.5.6.4 does not exist, explain what subsection this should refer to. If the intent was to refer to DCD subsection 2.5.4.3 - Settlement, then the information contained in this subsection does not explain how this settlement criteria ensures that the construction sequences evaluated and described in DCD Section 3.8.5.4.2 will be satisfied. To facilitate the resolution of this issue, it would be appropriate to include in the DCD the construction sequence limitations that were assumed in the set of construction sequence analyses described in the RAI response.

Additional Request (Revision 3):
(Follow-up RAIs dated 4/27/09 [note: this was based on review of the Rev 1 response])

The staff concurs (note: this was based on review of Rev 1) that DCD Rev. 17, Section 3.8.5.4.2, has been revised to update the information for the three construction sequences that were evaluated to demonstrate construction flexibility within certain limits. However, a statement in the RAI response indicates that 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. Since DCD subsection 2.5.6.4 does not exist, explain what subsection this should refer to. If the intent was to refer to DCD subsection 2.5.4.3 - Settlement, then the information contained in this subsection does not explain how these settlement criteria ensure that the construction sequences evaluated and described in DCD Section 3.8.5.4.2 will be satisfied. To facilitate the resolution of this issue, it would be more appropriate to include in the DCD the construction sequence limitations that were assumed in the set of construction sequence analyses described in the RAI response.

Additional Request (Revision 4):

The Westinghouse RAI response revised subsection 2.5.4.6.11 - Settlement of Nuclear Island, to state that, "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 (see subsection 3.8.5.4.2 for analyses of settlement during construction and the required limitations on construction sequence by the Combined License

applicant). Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values shown in Table 2.5-1."

The staff finds that this revision does not make it clear that in addition to meeting the settlement criteria presented in Table 2.5-1, the construction sequence limitations presented in subsection 3.8.5.4.2 must also be satisfied by the COL applicant. Westinghouse is requested to include such a clear statement in DCD Section 2.5.

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 subsections 2.5.4.3 and 2.5.4.6.11

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".

Westinghouse Response (Revision 2):

The response has been revised to correct the reference to DCD subsection 2.5.4.6.11 instead of 2.5.6.4. This subsection states: "Special construction requirements will be described, if required, to accommodate settlement predicted to exceed the values shown in Table 2.5-1." The construction sequence limitations assumed in the analyses are already described in DCD Rev 17 subsection 3.8.5.4.2.

The majority of sites will satisfy the values of Table 2.5-1. The special construction requirements will only apply at unusual very soft sites. Any additional discussion of this should be in the Combined License applications for such sites.

Westinghouse Response (Revision 3):

A reference to DCD subsection 2.5.4.3 has been added in the response to Item (e) above.

A revision is shown to the DCD subsection 2.5.4.6.11 referencing the construction sequence limitations that were assumed in the set of analyses described in the RAI response and described in DCD Section 3.8.5.4.2.

Westinghouse Response (Revision 4):

DCD Section 3.8.5.4.2 contains the following limitation on the construction sequence.

> prior to completion of both buildings (shield building and auxiliary building) 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″.

DCD Subsection 2.5.4.6.11 will be revised to clarify the reference to construction sequence limits in Subsection 3.8.5.4.2. Subsection 3.8.5.4.2 will be revised to clarify the applicability of the construction sequence limits.

These construction sequence limits were developed for a soft soil case. Based on consideration of the elastic settlement due to dead load, construction sequence limits are not required for soil properties that satisfy the requirements for rock sites in DCD Subsection 3.7.1. Construction at hard rock sites was approved in the certified design without construction sequence limits. The proposed DCD change excludes limits for soft, firm, or hard rock sites.

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. The following additional changes are required for Revision 3 and 4 of this response.

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 ~~(see~~ ~~s~~Subsection 3.8.5.4.2 ~~for~~ includes analyses of settlement during construction completed to support the design certification and the required limitations on construction sequence for some sites. ~~by the Combined License applicant).~~ The limitations on construction sequence impose limits on the placement of concrete for the shield building and the auxiliary building prior to completion of both buildings at elevation 82′ -6″. Special construction requirements will be described, if required, to accommodate site specific settlement predicted to exceed the values shown in Table 2.5-1.

Revise the seventh paragraph of Subsection 3.8.5.4.2 and the subsequent bulleted items as follows:

The analyses of alternate construction scenarios show that member forces in the basemat are acceptable subject to the ~~following~~ limits shown below, imposed for soft soil sites, on the relative level of construction of the buildings. Construction of the AP1000, when located at a soil site, will satisfy the limits shown below or a site specific analysis of settlement and member forces will be completed. These limits do not apply to AP1000 units with a soil profile that satisfies the requirements for soft rock, firm rock, or hard rock shown in Subsection 3.7.1.4,

P~~p~~rior to completion of both the shield building and auxiliary 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″.

PRA Revision:

None

Technical Report (TR) Revision:

No changes to Revision 1 of the Technical Report.

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: RAI-TR85-SEB1-32
Revision: 3

Question:

As shown by the studies in Section 2.7.1.2.1, when the soil is represented as solid elements rather than Winkler soil springs, higher bearing pressures occur at the edges and lower bearing pressures away from the edges. This is referred to as the effects of the Boussinesq distribution. Although this indicates that the basemat slab away from the walls would have higher bearing pressures using the Winkler soil spring approach (see Figure 2.7-2), the calculation of the maximum bearing pressure would still exist at the building edges if the soil is modeled as solid elements. Therefore, explain why the maximum bearing pressure for the AP1000 design, discussed in Section 2.4.2, should be based on the 2D ANSYS nonlinear dynamic analysis using Winkler soil springs rather than solid soil elements?

Additional Request (Revision 1):

The staff reviewed the RAI response submitted in Westinghouse letter dated March 31, 2008, and notes that the outstanding issues raised by this RAI are considered to be very significant. The RAI response states that the DCD "revision now indicates the line of lift-off, thereby defining the maximum total load applied to the foundation at the time of maximum demand...the dynamic bearing capacity is related to the overall loading on the foundation and to the shear strength mobilized over a failure surface in the foundation soils. The local maximum values close to the edge are not significant to this capacity and will redistribute if local stresses in the soil are excessive. This total load rather than a peak stress below an edge is to be considered by the Combined License applicant in demonstrating stability of the foundation material." Westinghouse is requested to address the following:

1. The above statements are not consistent with the criteria in the DCD because the statements indicate that the total load is used by the Combined License applicant to demonstrate the adequacy of the soil whereas, the DCD requires comparison of the maximum bearing pressure demand to bearing pressure capacity (e.g., DCD Tier 2, Section 2.5.4.2 and DCD Tier 1, Chapter 5.). Explain this inconsistency.

2. As noted in the original RAI, the studies in Section 2.7.1.2.1 demonstrate that when the soil is represented as solid elements, higher bearing pressures occur at the edges than when uniform Winkler type soil springs are used. This is a well known behavior in soil mechanics and is referred to as the Boussinesq effect. Since the current dynamic soil bearing pressure demand criterion of 35 ksf is still based on the 2D ANSYS stick model analysis, Westinghouse is requested to either (1) justify the statement that the localized peak soil pressures will redistribute if local stresses in the soil are excessive and the NI will still be stable or (2) explain what is the technical basis for using a uniform soil spring representation rather than soil brick

finite element or a soil spring distribution which more accurately captures the actual pressure distribution beneath the basemat.

3. The proposed revision to DCD Section 2.5.4.2 - Bearing Capacity, states that the "The maximum demand of 35 ksf occurs under the west edge of the shield building and is primarily due to the response to the east-west component of the earthquake. The east edge of the nuclear island lifts off the soil. The Combined License applicant will verify that the site specific allowable soil bearing capacities for static and dynamic loads at the site will exceed this demand. The evaluation may be limited to response in the east-west direction since the bearing demand is lower in the north-south direction." Explain what is meant by the statement that an "evaluation" may be limited to response in the east-west direction, because no "evaluation" or analysis to be performed by the applicant can be located in the DCD; instead the allowable soil bearing capacity needs to be shown to be greater than the bearing demand under static and dynamic loads.

Additional Request (Revision 2):
(Follow-up RAIs dated 4/27/09)

The RAI response indicates that the seismic analysis for determining the soil bearing pressure demand has been revised to utilize the SASSI 3D finite element NI20 model using a seismic time history soil-structure interaction analysis. This analysis was performed for the hard rock case and five soil conditions. The model includes a surrounding layer of excavated soil and the existing soil media. The soil media in SASSI is an idealization of the various horizontal soil layers. This representation of the soil in SASSI is considered to be more realistic and accurate than the uniform Winkler type soil springs used in the 2D ANSYS analyses, and thus addresses the concern regarding the calculation of soil bearing pressure demand. However, for the design of the basemat, Westinghouse has not demonstrated that its use of uniform Winkler type soil springs is adequate. As noted in the prior RAI, due to the Boussinesq effect in soil, the distribution of stiffness would be higher at the edges and lower away from the edges. Therefore, Westinghouse is requested to demonstrate that the use of the uniform soil springs for the design of the foundation is acceptable, when it is known that the actual distribution of the soil stiffness would not be uniform.

Additional Request (Revision 3):
NRC Meeting August 10-14

1. Clarify the Model identification in Table RAI-TR85-SEB1-32-1, Line 2 and Line 3. Consider use of description in Appendix 3G.
2. In the second paragraph on page 4 of 13 of the RAI response how does the referenced report from section 2.7.2 of TR85 demonstrate the acceptability of using Winkler springs instead of the method using Boussinesq effect.

Westinghouse Response:

Subsection 2.5.4.2 is being revised to clarify the maximum bearing pressure of 35 ksf, as stated in the DCD, it is obtained from analyses using uniform soil springs. The revision now indicates the line of lift off, thereby defining the maximum total load applied to the foundation at the time of maximum demand. Unlike the static case, where the allowable bearing capacity is controlled by settlements, the dynamic bearing capacity is related to the overall loading on the foundation and to the shear strength mobilized over a failure surface in the foundation soils. The local maximum values close to the edge are not significant to this capacity and will redistribute if local stresses in the soil are excessive. This total load rather than a peak stress below an edge is to be considered by the Combined License applicant in demonstrating stability of the foundation material.

Various analyses described in the report investigate the effect of modeling the soil with uniform spring and solid element representations. Comparisons are made in linear analyses using SASSI and ANSYS. Comparisons are made in ANSYS linear and non-linear analyses to show the effect of lift off. The analyses show small differences in the distribution of the bearing pressures but good agreement in the total loads imposed on the foundation material. The small differences in distribution (the Boussinesq effect) are not significant to the evaluation of the stability of the foundation material.

Westinghouse Response (Revision 1):

The maximum seismic bearing pressure demand defined for comparison to the subgrade pressure capacity is consistent with the DCD. See RAI-TR85-SEB1-03, Rev. 1 for discussion of the 35 ksf maximum bearing seismic demand.

In response to the many questions in this and other RAIs, Westinghouse has revised the basis for the bearing demand. The demand is now based on 3D SASSI analyses using the 3D NI20 finite element model as described in the response to RAI-TR85-SEB1-03, Rev 1. This change to use of the 3D SASSI results addresses the original question in this RAI. The additional questions in Rev 1 of this RAI apply to the Rev 0 response which has now been superseded.

The statement in the DCD Section 2.5.4.2, "The evaluation may be limited to response in the east-west direction since the bearing demand is lower in the north-south direction" has been removed. See DCD revision section below.

Westinghouse Response (Revision 2):

Table RAI-TR85-SEB1-32-1 shows the summary of the maximum reactions of the nuclear island for various soil and analysis methods. The results from Table 2.4-5 of the technical report, APP-GW-GLR-044, R1 (TR85), are shown for Item 1. Two other sources are contained in the table as comparison. The results of the linear analyses show consistent results demonstrating that the equivalent static analyses of the basemat result in bearing pressures

similar to a more realistic model represented in the 3D SASSI analyses presented in Table 2.4-5.

Section 2.7.1 of the technical report describes studies performed to evaluate the effect of different soil modeling. These studies analyzed a 3D finite element model of the complete nuclear island on soil finite elements or soil springs. Additional comparisons are provided in this response for the following soil models:

- Winkler soil springs of 520 kcf similar to the design analyses of the basemat (Model W)
- Finite element model of 80-foot deep soil layer below the nuclear island. The properties for this soil were selected to match the 520 kcf soil (Model L080).

Figure RAI-TR85-SEB1-32-1 shows bearing pressures due to dead load. The sections are located as shown in Figure 2.7-2 of the technical report. The RAI figure only shows the two cases identified above. The finite element soil model shows high local bearing pressures close to the edge. This is due to the Boussinesq effect. The higher pressures at the edge result in lower pressures away from the edge. Figures RAI-TR85-SEB1-32-2 and 3 show bending moment contours MX and MY for these two cases. It is seen that the bending moments for the soil spring case are higher than those for the soil finite element model even in the bays immediately adjacent to the edge.

Section 2.7.2 of the technical report describes an additional study performed to evaluate the basemat soil interaction. The north-west corner of the AP1000 shown in Figure RAI-TR85-SEB1-32-4 was modeled and analyzed in two dimensions using the non-linear VECTOR2 structural analysis program. The model of the basemat and soil is shown in Figure RAI-TR85-SEB1-32-5. The model of the basemat is 20269.2 mm (66.5') long, simulating 3 bays of 18' and ½ bay of 25', and 1828.8 mm (6') high. The element size is 152.4 mm (6") x 304.8 mm (12") for the first 55' and 152.4 mm (6") x 292.1 mm (11.5") for the last 11.5'. The total number of nodes and elements for the basemat is 884 and 804, respectively. The model of the soil is 23104.8 mm (75.8' depth) and 61069.2 mm (200.3'). The soil model extends almost twice the soil depth beyond the end of the basemat. The total number of nodes and elements for the soil is 4794 and 4642, respectively. The soil properties are chosen to give the same vertical displacement of the nuclear island under dead load as the 520 kcf soil springs. X-direction is horizontal and Y is vertical. The nodes on the last column are restrained in the X-direction to simulate symmetry. The VECTOR2 program considers cracking of the concrete and non-linear behavior of the reinforcement. Structural response is calculated up to failure for monotonically applied vertical displacement of the shear walls. Contact pressures on the soil are shown in Figure RAI-TR85-SEB1-32-6 (Figure 2.7-10, TR85) as a function of the applied displacement. They indicate substantial Boussinesq effect with high bearing pressures below the edge of the basemat. The analyses showed significant redistribution of soil bearing pressures as the load increased. The basemat withstood loading about three and a half times the design loads with final failure occurring in shear close to the exterior wall.

The studies documented in section 2.7 of the technical report and summarized above show the Boussinesq effect in rock and soil with an effective stiffness that is higher at the edges and lower away from the edges. This distribution is presented on Figure RAI-TR85-SEB1-32-7. The influence values represent the effect of the contact on a half space beneath a rigid circular footing. The Boussinesq equation does not account for the influence of the basemat's embedment depth of 39.5 feet which would increase the bearing capacity of the foundation. Because of the basemat dimensions (plan and thickness), the foundation would be considered flexible. The studies demonstrate that the use of uniform Winkler type soil springs is adequate for a flexible mat foundation.

Westinghouse Response (Revision 3):

1. The 2D SASSI model listed at Line 2 of Table RAI-TR85-SEB1-32-1 refers to the East-West 2D stick model described in section 2.4.1 of APP-GW-GLR-044, and also shown in Figure 2.4-2 of that report. The 2D Time History model listed at Line 3 of the table refers to the lift-off analysis performed in ANSYS described in section 2.4.2 of APP-GW-GLR-044, and shown in Figure 2.4-4 of that report.

2. The referenced report, from section 2.7.1 of TR85, demonstrates the acceptability of using Winkler springs instead of the method using Boussinesq effect. As concluded in section 2.7.1.2.4, the analyses with finite element models of the soil were performed as linear elastic analyses. They require much greater computer running time and do not lead to significantly better results. The design analyses are non-linear to consider lift off. They require a more detailed model of the nuclear island than that used in the studies. They must address more combinations of seismic input than used in the studies. Hence Winkler springs were selected for use in the design analyses similar to those used in the AP600 analyses.

   As discussed in section 2.7.1.2.1, the models with finite element representation of the soils show larger bearing reactions at the edges than the Winkler spring model. These higher reactions at the edges give a corresponding reduction of bearing reactions and member forces away from the edges. Hence the uniform Winkler springs are conservative for design of the basemat since reinforcement in the basemat is controlled by member forces below the center of each panel and the interior walls (the exterior wall acts more like a simple support than a fixed support).

   The referenced report from section 2.7.2 of TR85 does not directly demonstrate the acceptability of using Winkler springs instead of the method using Boussinesq effect. However, it shows substantial margin (about three and a half times the design loads) in the design with a more detailed soil and structure model that also shows bearing pressures consistent with the Boussinesq distribution.

Table RAI-TR85-SEB1-32-1

Maximum Basemat Bearing Pressure (Summary)

No.	Method of Analysis	Foundation Conditions					
		HR (ksf)	FR (ksf)	SR (ksf)	UBSM (ksf)	SM (ksf)	SS (ksf)
1	3D SASSI, NI20 Model, TH + vertical earthquake	35.0 *	27.9	24.0	25.7	23.1	21.9
2	2D SASSI, ni2D** model	29.1	24.0	24.5	27.4	30.2	20.2
3	2D ANSYS Time History, ni2D** model: Linear	32.8	N/A	N/A	31.7	30.8	N/A
	:Lift off	34.9	N/A	N/A	33.5	32.2	N/A

Notes:

* 38.3 ksf was the maximum localized peak calculated; a limit of 35 ksf for maximum bearing seismic demand is obtained by averaging the soil pressure about the West edge of the shield building where the maximum stress occurs.

** The ni2D model refers to the East-West 2D stick model of the Nuclear Island used for the SASSI and ANSYS analyses. The SASSI analysis used the model embedded in soil 120' below grade. The ANSYS linear lift off model was a non-linear analysis on a rigid basemat. The SASSI and ANSYS model representations are shown in TR85, Figures 2.4-2 and 2.4-4 respectively.

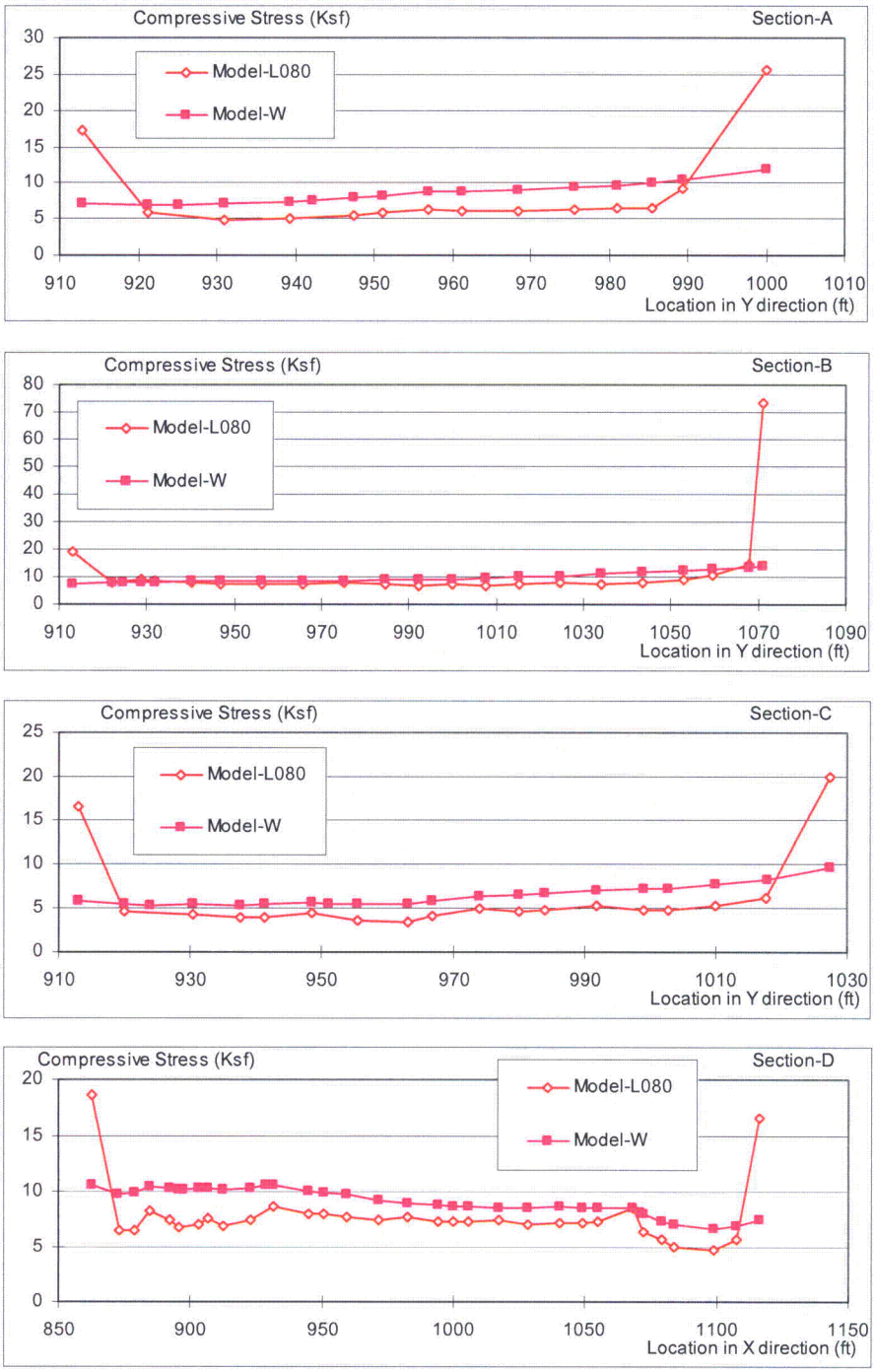
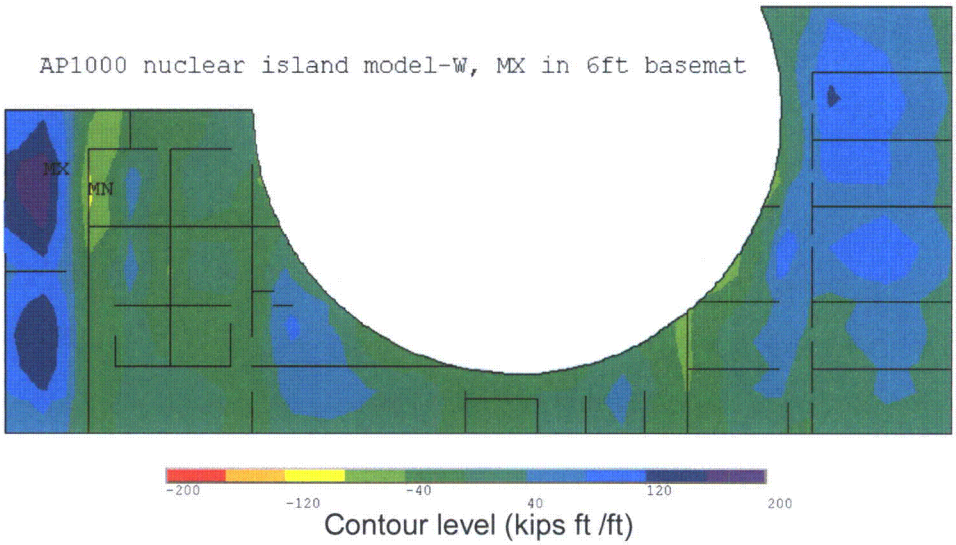


Figure RAI-TR85-SEB1-32-1
Comparison of Vertical Stress at Basemat Bottom Node – No embedment



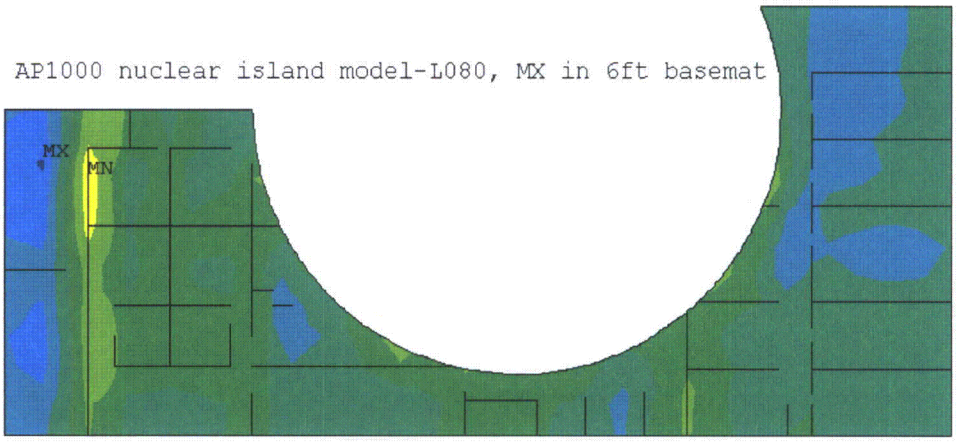
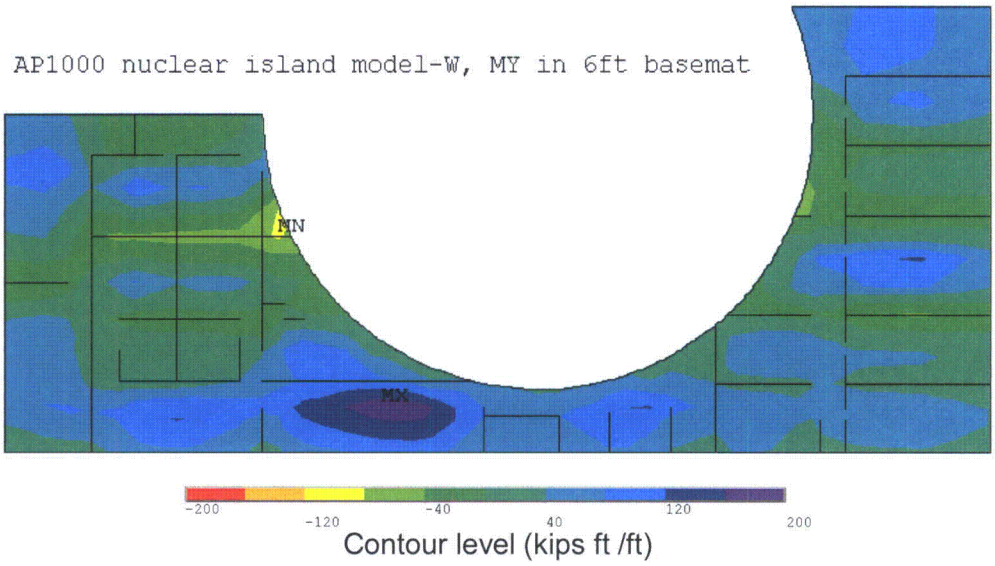


Figure RAI-TR85-SEB1-32-2 Bending Moment MX for Model-W and Model-L080



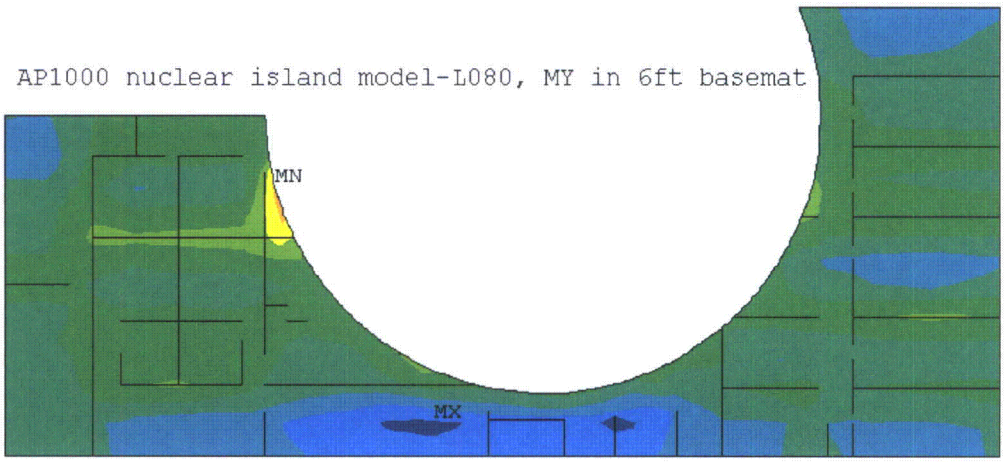


Figure RAI-TR85-SEB1-32-3 Bending Moment MY for Model-W and Model-L080

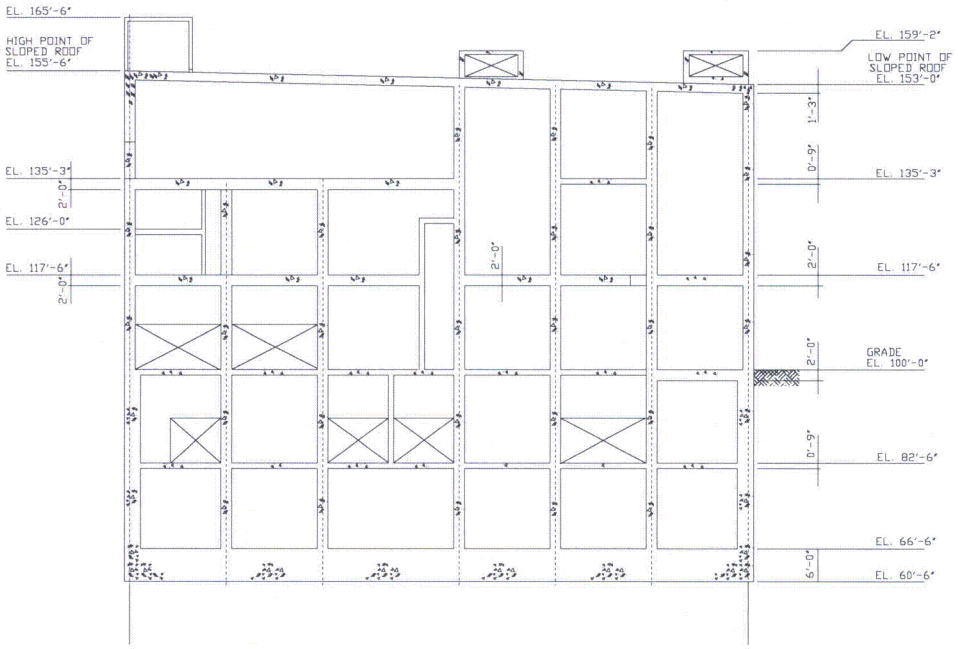


Figure RAI-TR85-SEB1-32-4

Cross section through north end of auxiliary building looking south

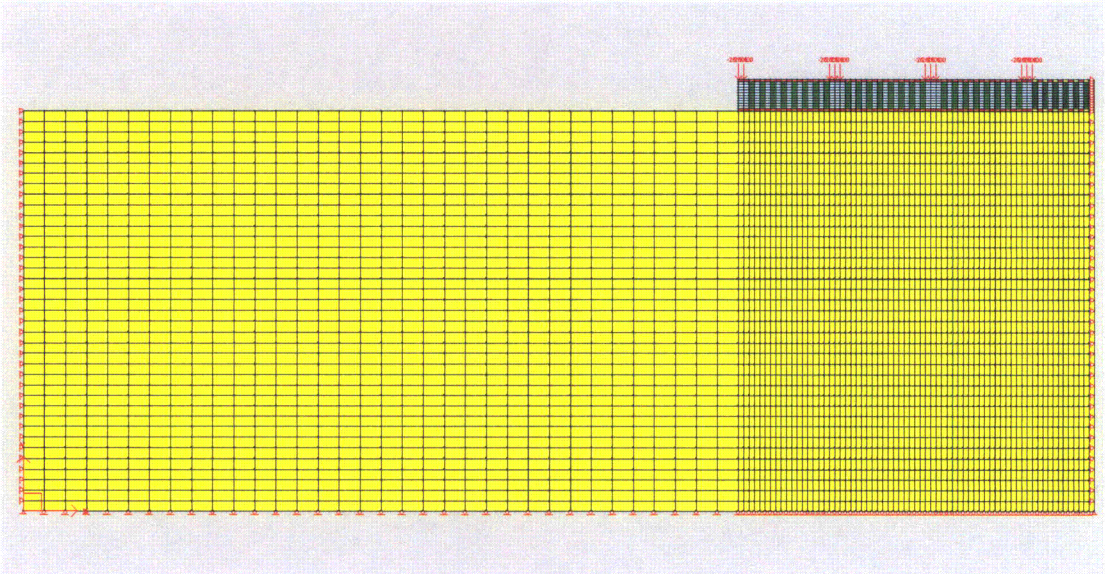


Figure RAI-TR85-SEB1-32-5

Vector2 model looking north with Soil Elements

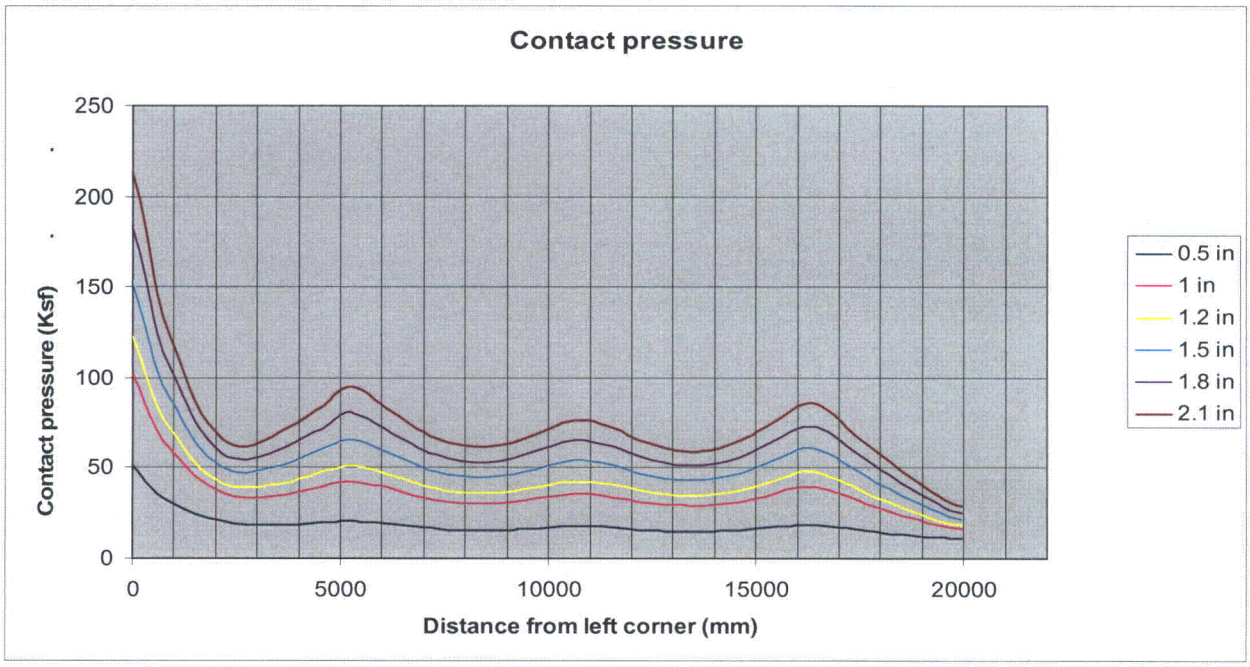
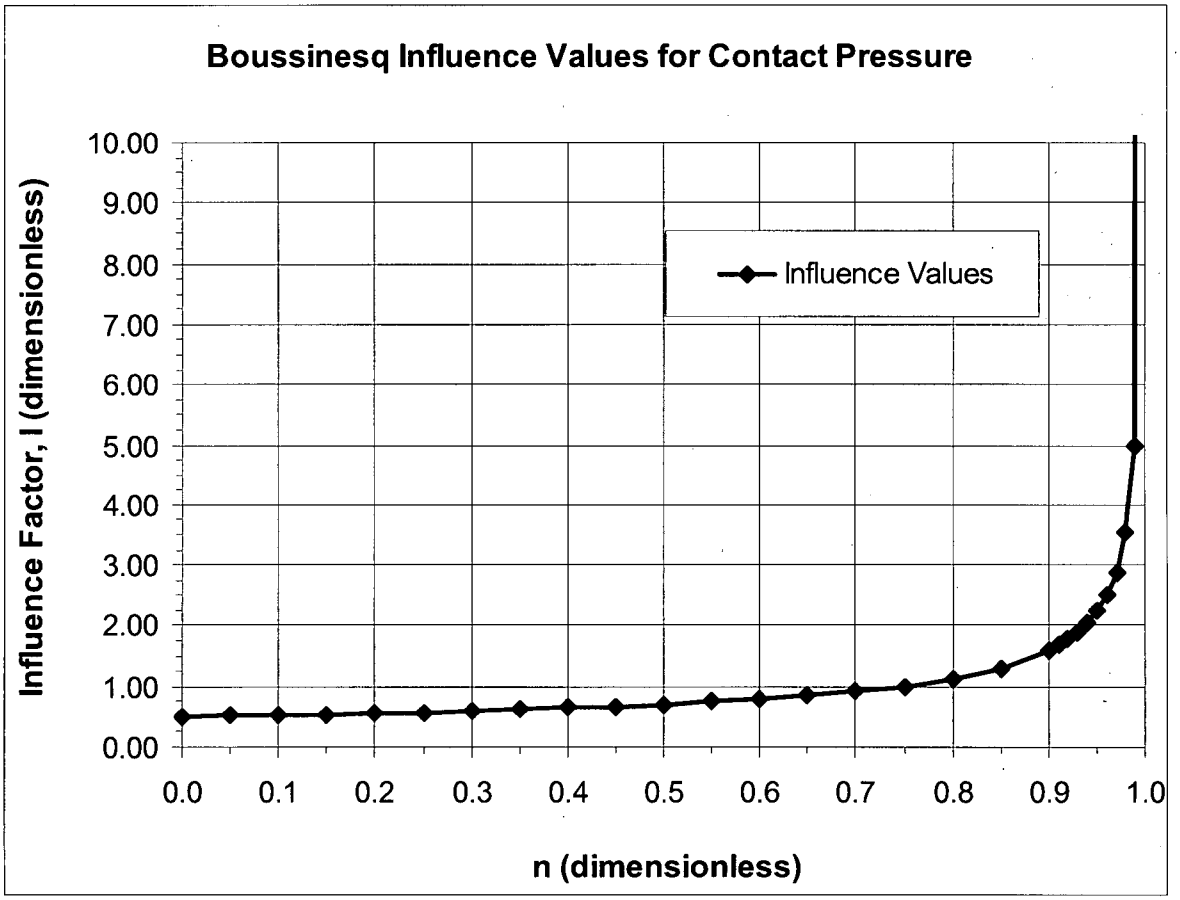


Figure RAI-TR85-SEB1-32-6
Contact Stresses along Mat for Half Space



Notes:
Area (sf) = 32,480 (for NI footprint)
r (ft) = 101.68 (r for equivalent area)
If n = 0.0 is the center of the area (r = 0.0 ft)
then n = 1.0 at the perimeter (r = 101.68 ft),

Boussinesq Method (rigid circular footing)
Qo = Footing Contact Pressure
P = Foundation Load, A = Footing Area
$Qo = (P / A) \times (1 / 2x(1-n)^{0.5})$

with $I = \dfrac{1}{2\,(1-n)^{0.5}}$

Figure RAI-TR85-SEB1-32-7
Boussinesq Influence Values for Footing Contact Pressure
(rigid circular footing at ground surface, for half space)

Design Control Document (DCD) Revision:

All changes to the DCD shown in this section are from previous revisions of this RAI. No additional changes have been made to the DCD in Rev 3 of this response.

The changes to the DCD shown in Rev 0 of this RAI response have been implemented in DCD Rev 17. Revise first paragraph of DCD Rev 17 subsection 2.5.4.2 as follows:

2.5.4.2 Bearing Capacity

The maximum bearing reaction determined from the 3D SASSI analyses described in Appendix 3G is less than 35,000 lb/ft^2 under all combined loads, including the safe shutdown earthquake. ~~These analyses use uniform soil springs below the basemat.~~ The maximum dynamic bearing demand of 35 ksf occurs under the west edge of the shield building and is primarily due to the response to the east-west component of the earthquake. The east edge of the nuclear island lifts off the soil. The Combined License applicant will verify that the site-specific allowable soil bearing capacities for static and dynamic loads at the site will exceed the static and dynamic bearing demand given in Table 2-1. ~~The evaluation may be limited to response in the east-west direction since the bearing demand is lower in the north-south direction.~~

PRA Revision:

None

Technical Report (TR) Revision:

Revise Tables 2.6-2 (b), 2.6-2 (c) and 2.6-4 as shown below:

Table 2.6-2 (b), revise footnote 2 as follows:

2. Equivalent static results ~~for three directions are combined by SRSS~~are shown for the response from one direction, (i.e FX and MYY due to X input, FY and MXX due to Y input, and FZ due to Z input. The increase due to combination of three directions is small.

Table 2.6-2(c)

Maximum soil bearing pressures (ksf) at corners from basemat reactions

Location	Equivalent static accelerations Linear analyses	Fixed base time history all soils
West side of shield building	~~35.9~~36.8	36.9
NW corner of auxiliary building	~~24.4~~27.1	24.8
NE corner of auxiliary building	~~25.1~~22.8	25.5
SE corner of auxiliary building	~~24.7~~21.1	25.1
SW corner of auxiliary building	~~27.0~~29.6	27.1

Table 2.6-4, revise footnotes as follows:

Note 1: See Figures 2.6-9 and 2.6-10 for plan and elevation schematic views of the reinforcement layout.

Note 2: Figures 6-1 and 6-2 in APP-1010-CCC-004, Rev.0 provide graphical presentation of the "Required" (red dash line) and "Provided" (solid black line) areas of radial reinforcement for the top face of the Dish.