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Your ref: Docket No. 52-006
Our ref: DCP/NRC2501

May 27, 2009

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

Westinghouse is submitting a response to the NRC request 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-SEB1-02 R2

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

D063
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-SEB1-02
Revision: 2

Question:

In Section 2.2.1, the second paragraph (Page 7 of 83) states that for the AP600 basemat analyses and design, the reactions on the side walls below grade were conservatively neglected for calculating horizontal soil springs. Was this assumption also applied to the AP1000 basemat and foundation analyses? If so, provide the technical basis which demonstrates that it is conservative to neglect the reactions on the side walls below grade for calculating horizontal soil springs. Also, explain how the reactions on the side walls below grade were calculated and how they were considered in the design of the foundation walls and basemat. Were passive soil pressures on the side walls calculated and applied to the 3D ANSYS equivalent static nonlinear analysis?

Additional Request (Revision 1)

The staff reviewed the RAI response provided in Westinghouse letter dated 9/28/07, and noted that the response does not provide sufficient information. Westinghouse is requested to explain how the reactions on the side walls below grade were calculated (i.e., description of the analysis approach used to calculate the loadings for each of the lateral earth pressures listed in the RAI response), and how they were applied to the walls for design of the foundation walls and basemat (e.g., the calculated pressures applied to the overall 3D ANSYS finite element model [specify which model] and whether a linear elastic static analysis was used).

When providing this information, Westinghouse is requested to incorporate the resolution of the related issues on passive soil pressure raised under the staff's follow-up RAIs TR85-SEB1-34, 35 and 40.

Additional Request (Revision 2)

The RAI response provided a description of the reactions on the exterior walls below grade subjected to the various loads including lateral earth pressure loads. The analytical approach to calculate the pressure loads presented in the RAI response consisted of hydrostatic, at rest earth pressure, surcharge pressure, dynamic earth pressure, and passive earth pressure. In the case of seismic earth pressure loads, the approach was performed in accordance with ASCE 4-98, Section 3.5.3, which utilizes the elastic solution for dynamic soil pressures. In addition, the passive pressure loads needed to resist sliding during an SSE are also considered in the design of the exterior walls below grade. From the information provided it is not clear that lateral soil pressure loads, caused by vertical seismic loading of the soil, had been considered in the design of the foundation. In addition, the RAI response does not provide the vertical profile of lateral earth pressure loads on embedded walls from the 3D SASSI analyses, the ASCE approach, and the passive soil pressure loads used for the stability analyses, and how the walls were designed from these three vertical profiles of lateral earth pressure loads. Therefore, Westinghouse is requested to explain and provide the following two items:

(1) Explain how the lateral soil pressure loads, caused by vertical seismic loading of the soil, were determined and how were they considered in the design of the foundation.

(2) Provide the vertical profile of lateral earth pressure loads on embedded walls from each of the following analysis methods: 3D SASSI, ASCE approach, and the passive soil pressure load approach used for the foundation stability evaluation, and describe how the walls were designed from these vertical profiles of lateral earth pressure.

Westinghouse Response:

The vertical and horizontal soil springs are described in DCD Subsection 3.8.5.4.1 as follows:

> *The subgrade is modeled with one vertical spring and two horizontal springs at each node of the basemat. The vertical springs act in compression only. The horizontal springs are active when the vertical spring is closed and inactive when the vertical spring lifts off. The analyses of the basemat accounted for the range of soil sites described in Section 2.5. Horizontal bearing reactions on the side walls below grade are conservatively neglected.*

The assumption that “the reactions on the side walls below grade were conservatively neglected for calculating horizontal soil springs” is made in both the AP600 and the AP1000 basemat analysis.

The horizontal soil spring stiffness has only a minor effect on the basemat member forces. Horizontal loads are resisted by the portion of the basemat that remains in contact with the soil and generally puts the basemat in membrane compression. If forces are taken out by the side soils as well as the foundation soils, the membrane compression forces would increase. This would reduce the reinforcement demand in the basemat. Hence neglecting the load transfer into the side soil is conservative in the design of the basemat reinforcement away from the edges.

Lateral earth pressure was applied on the side walls below grade in linear elastic analyses for the following cases:

- *Ground water*
- *At rest earth pressure*
- *Static surcharge*
- *Dynamic earth pressure*
- *Dynamic surcharge*
- *Passive earth pressure*

Results of these analyses were used in design of the exterior walls and were also combined with the results of the non-linear basemat analyses for design of the basemat reinforcement. The design of the basemat close to the edge is affected by the moments at the base of the exterior walls due to the lateral earth pressure.

Westinghouse Response (Revisions 1 and 2):

The Nuclear Island exterior walls below grade are subjected to various loads including the lateral earth pressure loads that were identified in the Revision 0 Westinghouse response.

Lateral loads used in design of the nuclear island are based on conservative assumptions (soil profiles with highest lateral loads) for the properties of the soil adjacent to the exterior walls. Lateral loads are calculated for a range of possible soil properties and a conservative set of loads is specified for design.

The plant grade elevation is 100'-0", the high ground water level is 98'-0", and the maximum flood level is at plant elevation 100'-0".

The analysis method used to calculate the lateral earth pressure loads is given below.

LOAD CONDITIONS

Hydrostatic (gound water) (Live, L)

The design high ground water level is at Elevation 98'-0", and the probable maximum flood level is at Elevation 100'-0". Both of these loads are treated as live loads. The flood level of Elev. 100'-0" is represented in the Schematic Load Diagram in Figure RAI-TR85-SEB1-02-2A for use in plotting the load combination results presented in Figure RAI-TR85-SEB1-02-3. The hydrostatic unit water pressure (P_w) at a depth h (units: feet) below ground level is calculated as:

$$P_w = \gamma_w h \qquad (1)$$

Where, γ_w = unit weight of water = 62.4 pcf

At--Rest Earth Pressure (Earth, H)

Static earth pressure is based on "at--rest" conditions, and the coefficient of earth pressure for the at-rest condition (K_o) is determined from the following relationship:

$$P_o = K_o \gamma h \qquad (2)$$

Where,

$K_o = 1\text{-SIN}(\phi)$

ϕ = angle of internal friction
h = depth below grade (El. 100' 0")
$\gamma = \gamma_s$ = Saturated unit weight of granular back fill above water table. **or**
$\gamma = \gamma_s - \gamma_w$ below water table

Static and Dynamic Surcharge Pressures

The static surcharge pressure (Dead, D) is considered a static pressure load, and therefore, the at-rest coefficient (K_o) is used. The static lateral surcharge pressure is defined for the same soil case as the at-rest pressure as follows:

$$P_{surch} = K_o\, q \qquad (3)$$

Where,
q = static surcharge pressure based on footprint loads of adjacent structures

The dynamic lateral surcharge pressure (Seismic, Es_2)is based on 0.3 times the static surcharge pressure. The static and dynamic lateral surcharge pressures act uniformly along the height of the exterior walls.

Dynamic Earth Pressure (Seismic, Es_2)

The dynamic earth pressure is calculated in accordance with ASCE 4-98 (Reference 1), Section 3.5.3, Figure 3.5-1, "Variation of Normal Dynamic Soil Pressures for the Elastic Solution." The Poisson's ratio (ν) for the soil varies between 0.35 and 0.4. The most conservative dynamic soil pressure distribution, obtained using 0.4 for ν, is used. The seismic acceleration levels are the maximum accelerations associated with the seismic response of the nuclear island from Elev. 60.5 to Elev. 100. The N-S seismic excitation acceleration values are associated with Walls 1 and 11. The E-W seismic acceleration values apply to Walls N, Q and I.

Passive Earth Pressure (Seismic, Es_3)

The Nuclear Island includes passive pressure on the exterior walls to resist sliding during an SSE. Therefore, the exterior walls below grade shall also be designed for passive earth pressure in the load combinations that include Es. The passive earth pressure is calculated from:

$$P_P = K_P\, \gamma\, h \qquad (4)$$

Where,
$K_P = \tan^2(45° + \phi / 2)$

ϕ = angle of internal friction
h = depth below grade (El. 100' 0")
$\gamma = \gamma_s$ = Saturated unit weight of granular back fill above water table **or**
$\gamma = \gamma_s - \gamma_w$ below water table

Schematic Load Diagrams

Figures RAI-TR85-SEB1-02-2A and -2B present schematic diagrams of the lateral pressures for the load conditions discussed above. These load conditions

Load Combinations

Lateral loading conditions, identified above and in Table RAI-TR85-SEB1-02-1, are used for the following load combinations:

Load Combination 3: **(L) + (H) + (D) + (Es_1) + (Es_2)**

Load Combination 7: **(L) + (D) + (Es_1) + (Es_3)**

Load Combinations 1 & 2: **1.4 x (D) + 1.7 x ((L) + (H))**

Load Combinations 4, 5 & 6: **(L) + (H) + (D)**

Load Combinations 8 & 9: **1.05 x (D) + 1.3 x ((L) + (H))**

The design of the exterior below grade walls are designed from the load combinations listed above which incorporates the effects of full lateral passive earth pressure.

The load combinations, listed above, are graphically presented on Figure RAI-TR85-SEB1-02-3. The values for the static and dynamic lateral surcharge pressures represent the maximum influence of the Annex Building (Line I, 9 to 11) along the East-West axis and the Turbine Building alone the North-South axis. This figure also presents the graphs of the load conditions incorporating the seismic event in either the North-South or East-West axis of the Nuclear Island.

Based on the tabular results for the load combinations, as illustrated on Figure RAI-TR85-SEB1-02-3, the critical lateral pressure distribution for the design loads along the exterior, below grade walls would result when combining the effects of Load Combinations (LC) 3 and 7 along the N.I.'s E-W axis. The pressure distribution for LC 3 would control from Elev. 100 (ground surface) to the intersection with the LC 7 pressure distribution. Graphically, this occurs at approximately Elev. 91. The LC 7 plot would control from this intersection to Elev. 60.5 (bottom of the basemat). LC 7 incorporates the effects of full lateral passive earth pressure.

Lateral Soil Pressure with Vertical Seismic Effects

The graph of "Soil Pressure – Vertical Seismic" in Figure RAI-TR85-SEB1-02-4 presents the At-rest Earth Pressure (for the generic soil model or Case 15 Soil) multiplied by 0.3 (seismic acceleration factor). This same factor was used to determine the dynamic lateral surcharge pressure (Seismic, Es_2) noted above. These tabular values where combined with the values from the Dynamic Soil Pressure (along the East-West axis) by the SRSS Method (square root, sum of squares) and plotted against the Dynamic Soil Pressure (along the East-West axis) alone. As shown on the plot, the contribution of vertical seismic effect on the at-rest earth pressure is negligible to the Dynamic Soil Pressure plot. Therefore, vertical seismic effect is negligible and the Dynamic Soil Pressure alone was used in determining the load combination.

3D SASSI Analyses

Utilizing the NI20 coarse model, 3D SASSI soil-structure interaction analyses for soil conditions soft to medium (SM) and upper bound soft to medium (UBSM) soil were used to estimate the dynamic soil pressure on the exterior NI walls. Five (5) locations were used to calculate lateral pressure on the structure including spring elements at Elev. 100 and 82.5, and structure elements at Elev. 91, 71 and 57. Axial spring forces normal to and along each wall are tabulated and converted to a unit load and corresponding stress at each elevation. Similarly, element stresses normal to the plane of the wall are tabulated for each elevation and the maximum normal stress was determined.

Dynamic soil pressures from the 3D SASSI analyses for the UBSM and SM soil conditions are plotted at Elev. 100, 91, 82.5, 71 and 57, and the pressure distribution curves for the vertical profiles of each wall were generated. The 3D SASSI UBSM and SM dynamic soil pressure for the North-South and East-West vertical profiles are compared to the ASCE 4-98 lateral soil pressure distribution curve. These results are presented on Figures RAI-TR85-SEB1-02-5A (North-South) and RAI-TR85-SEB1-02-5B (East-West).

3D ANSYS Analyses

The analyses of the Nuclear Island for the lateral earth pressure loads are performed using 3D linear elastic ANSYS analysis. The NI05 model is used that is shown in Figure RAI-TR85-SEB1-02-1. The lateral earth pressure loads are applied to the finite element nodes associated with embedded Nuclear Island structural walls. The analysis performed is linear elastic. Loads and moments at the base of the exterior walls are extracted from NI05 analyses and are added in the design analyses of the basemat.

References:

1. ASCE Standard, ASCE 4-98, "Seismic Analysis of Safety-Related Nuclear Structures and Commentary."

Table RAI-TR85-SEB1-02-1 – Load Combinations

Hydrostatic Load	At-Rest Pressure	Static Surcharge Pressure	Dynamic Surcharge Pressure	Dynamic Earth Pressure	Passive Earth Pressure
Live, L	Earth, H	Dead, D	Seismic, Es_1	Seismic, Es_2	Seismic, Es_3

Notes to Table RAI-TR85-SEB1-02-1:

1. During a seismic event (Load Combination 7), the At-Rest Pressure (H) is considered to revert to the Passive Earth Pressure (Es_3) and therefore not considered in load combinations with Passive Earth Pressure. It is considered with Dynamic Earth Pressure (Es_2).
2. In load combinations with Es (Load Combinations 3 and 7), the Dynamic and Passive Earth Pressure Loads are considered separately. Therefore, a separate load combination with Dynamic Earth Pressure (Es_2) is considered, and another load combination is considered for Passive Earth Pressure (Es_3).

Table RAI-TR85-SEB1-02-1 – Load Combinations (continued)

Load combinations are based on DCD, Revision 17, Table 3.8.4-2.

Table 3.8.4-2

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

Combination No.		Load Combination and Factors								
		1	2	3	4	5	6	7	8	9
Load Description										
Dead	D	1.4	1.4	1.0	1.0	1.0	1.0	1.0	1.05	1.05
Liquid	F	1.4	1.4	1.0	1.0	1.0	1.0	1.0	1.05	1.05
Live	L	1.7	1.7	1.0	1.0	1.0	1.0	1.0	1.3	1.3
Earth	H	1.7	1.7	1.0	1.0	1.0		1.0	1.3	1.3
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
Safe shutdown earthquake	E_s			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		

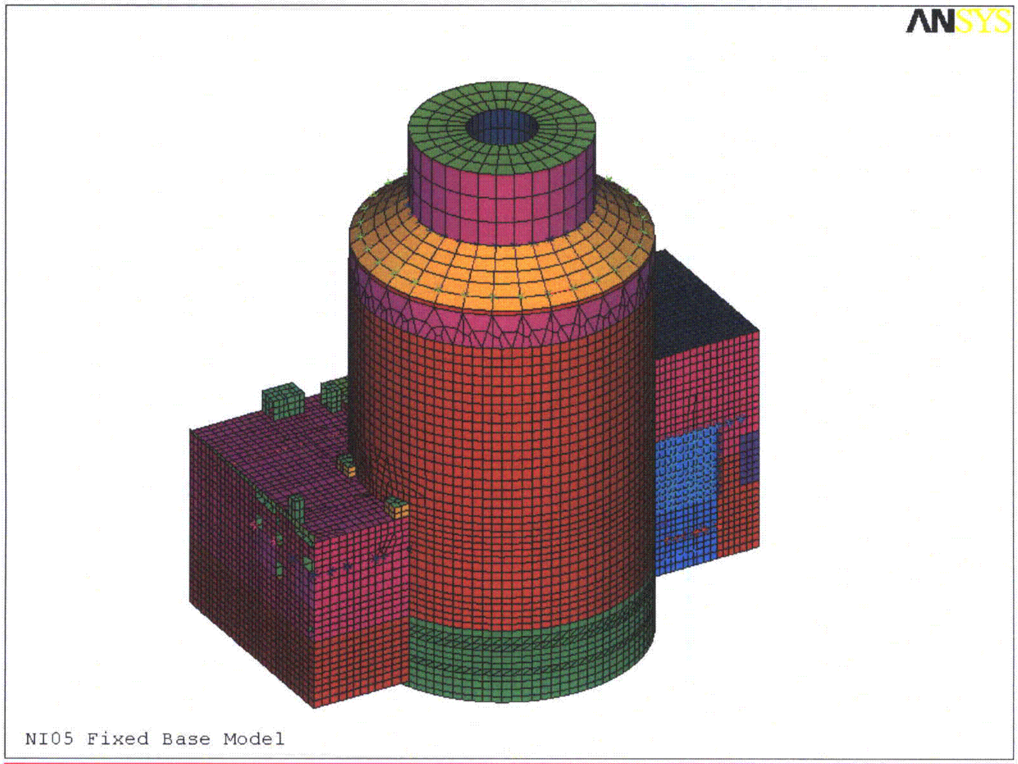


Figure RAI-TR85-SEB1-02-1 - NI05 Model (from North-West)

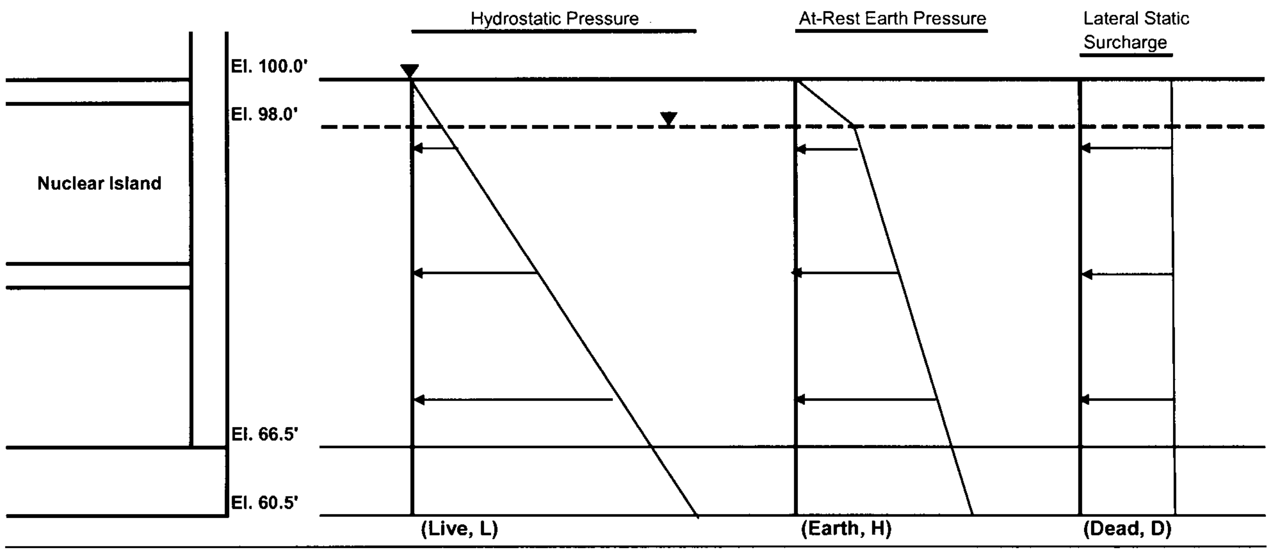


Figure RAI-TR85-SEB1-02-2A – Schematic Load Diagrams for Live, Earth and Dead Loads

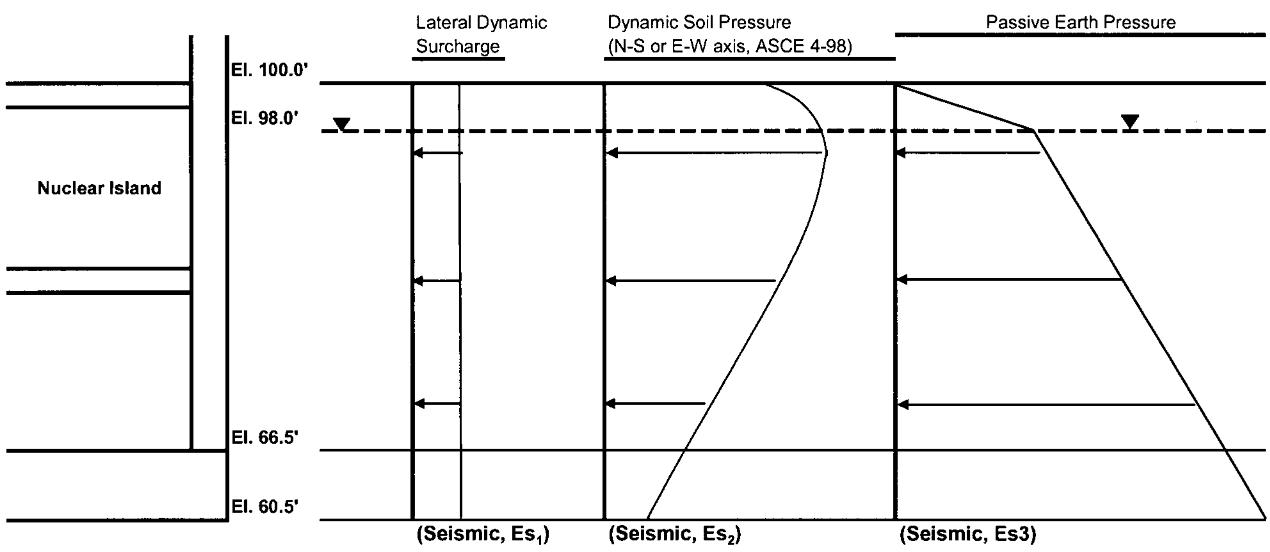
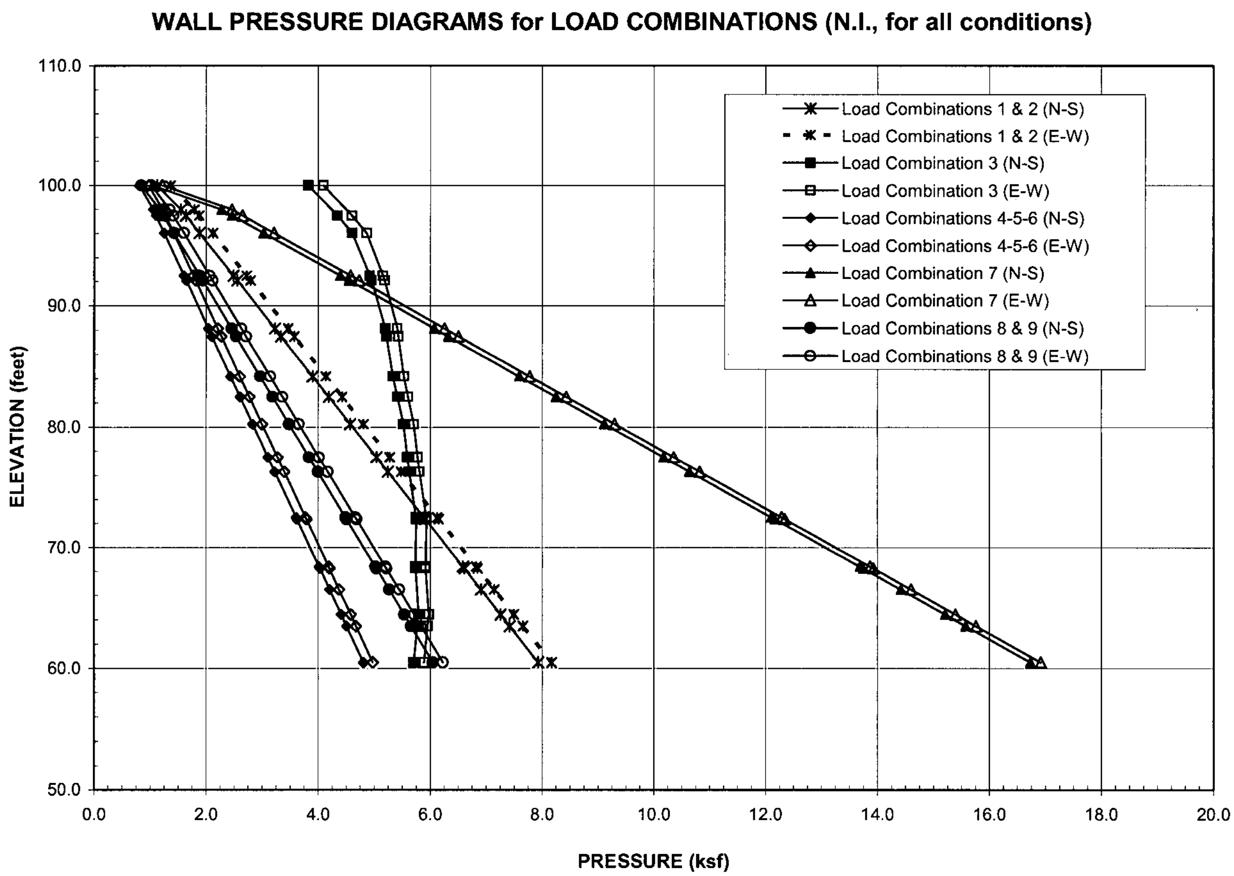


Figure RAI-TR85-SEB1-02-2B – Schematic Load Diagrams for Seismic Loads Es_1, Es_2, and Es_3



Plant North

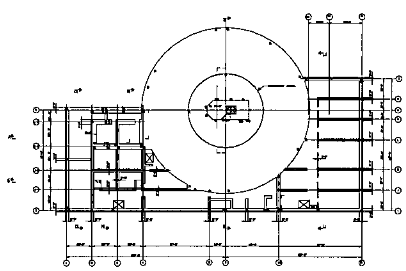
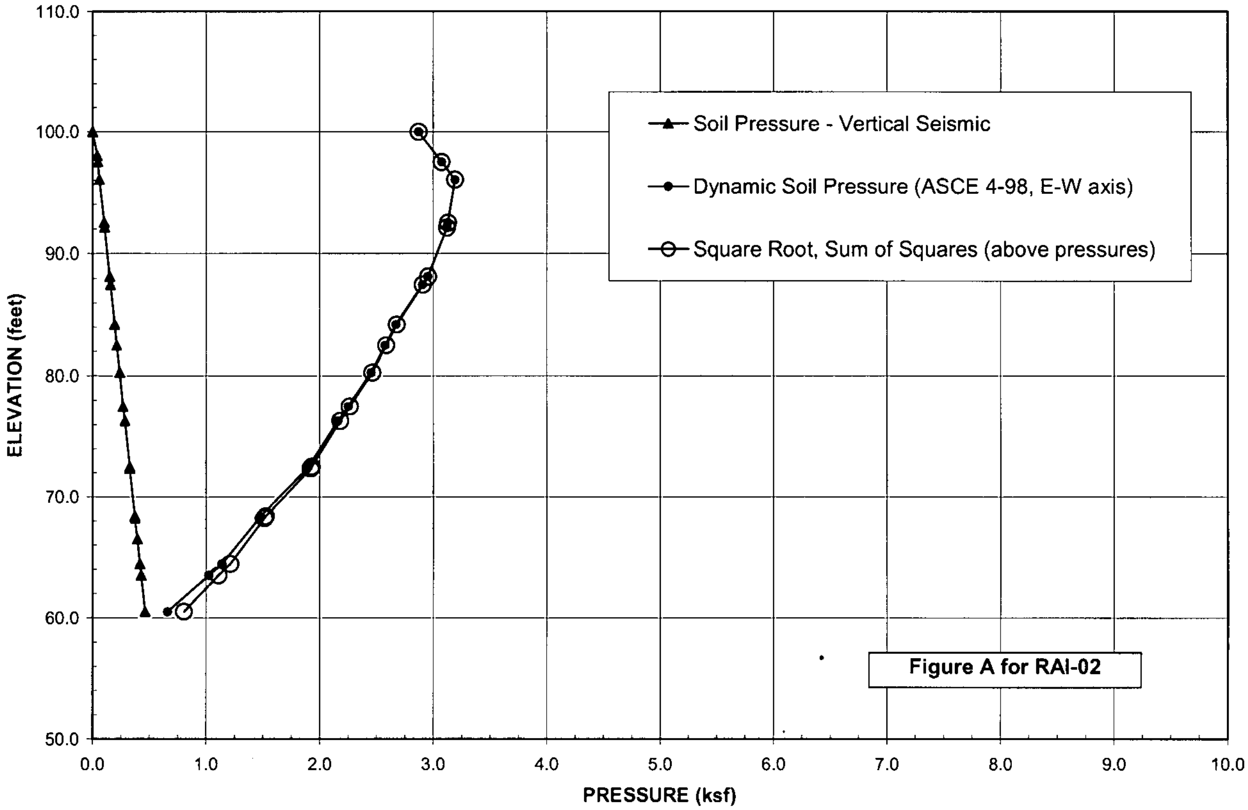
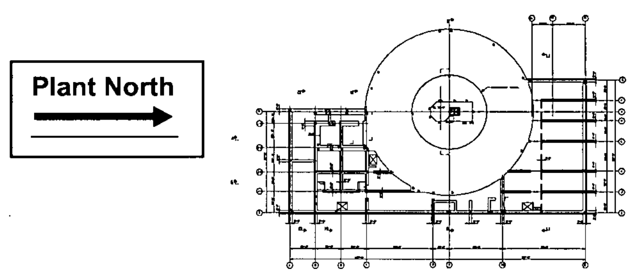


Figure RAI-TR85-SEB1-02-3 – Exterior Wall, Design Load Pressure Diagrams

WALL PRESSURE DIAGRAMS for LATERAL LOADS (N.I., for all conditions)





<u>Figure RAI-TR85-SEB1-02-4 – Seismic Effects on Lateral Soil Pressure</u>

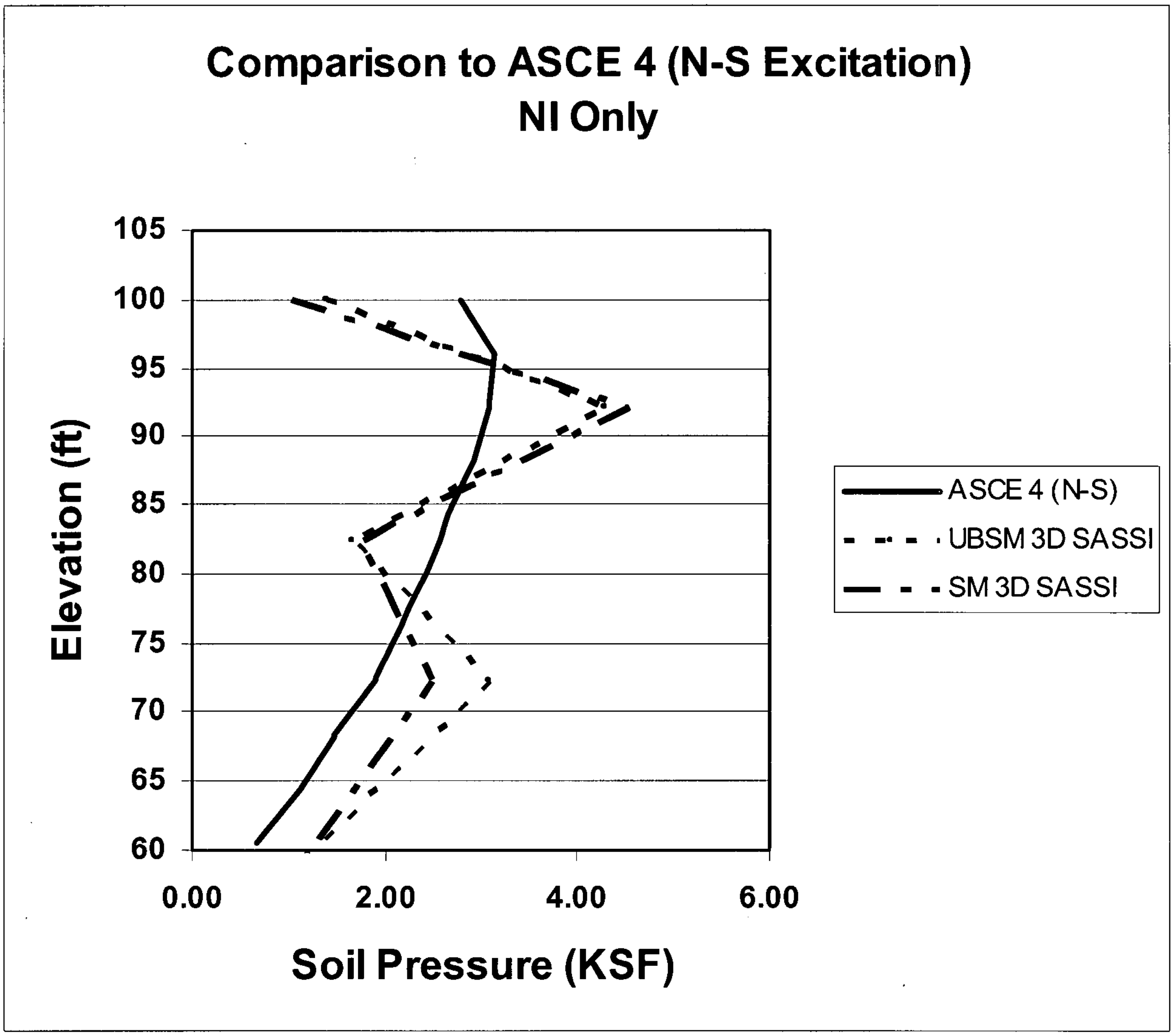


Figure RAI-TR85-SEB1-02-5A – North-South NI Soil Pressure Comparison (ASCE 4-98 and 3D SASSI for UBSM and SM soil)

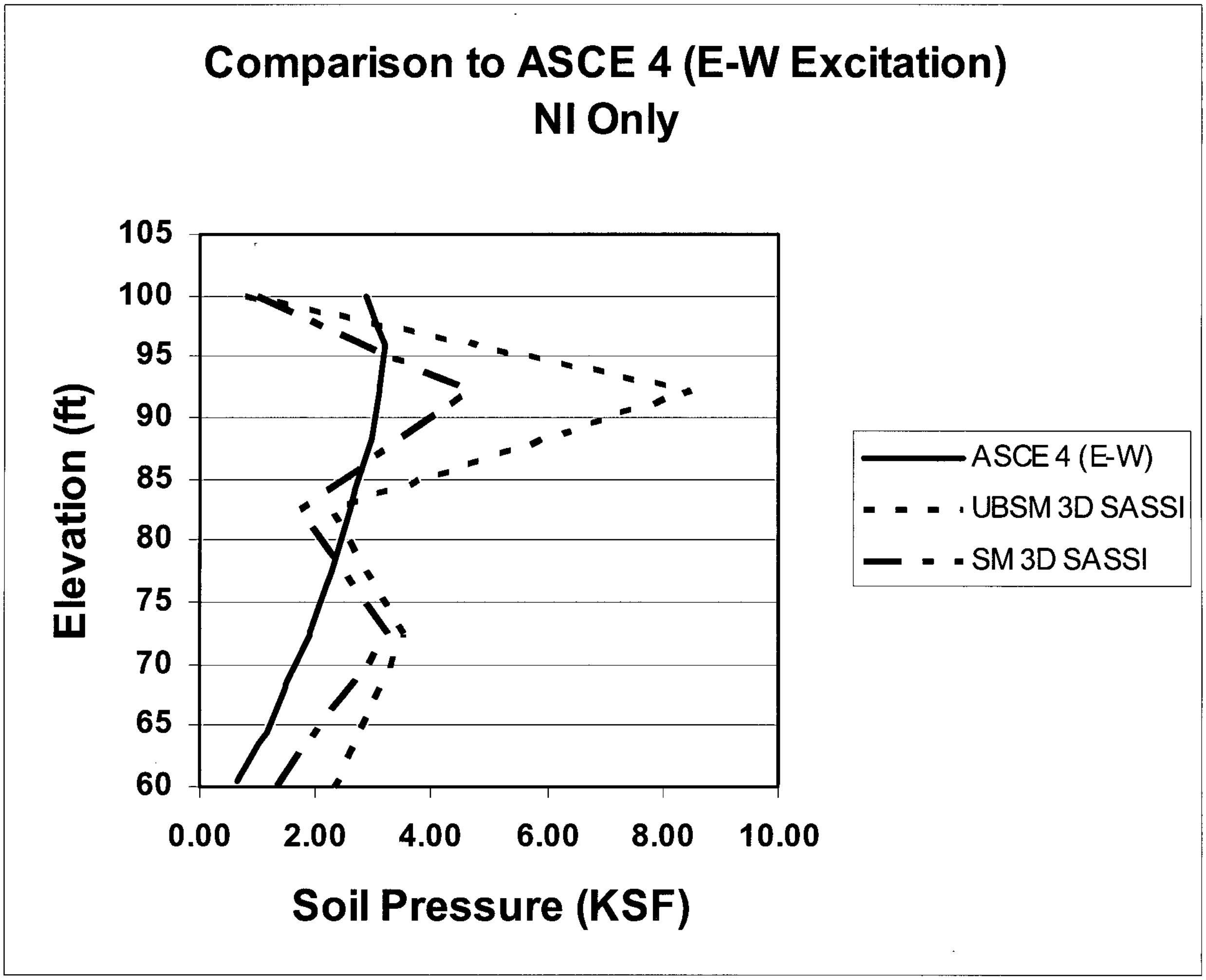


Figure RAI-TR85-SEB1-02-5B - East-West NI Soil Pressure Comparison (ASCE 4-98 and 3D SASSI for UBSM and SM soil)

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None