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NUCLEAR ENERGY

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August 25, 2011

UN#11-237

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: UniStar Nuclear Energy, NRC Docket No. 52-016
Response to Request for Additional Information for the
Calvert Cliffs Nuclear Power Plant, Unit 3,
RAI No. 304, Seismic System Analysis

Reference:
1) Surinder Arora (NRC) to Robert Poche (UniStar Nuclear Energy), "FINAL RAI 304 SEB2 5717, dated May 11, 2011.

2) UniStar Nuclear Energy Letter UN#11-203, from Greg Gibson to Document Control Desk, U.S. NRC, Response to RAI No. 304, Seismic System Analysis, dated July 8, 2011.

3) UniStar Nuclear Energy Letter UN#11-240, from Greg Gibson to Document Control Desk, U.S. NRC, Calvert Cliffs Nuclear Power Plant, Unit 3 RAI Closure Plan, dated August 23, 2011.

The purpose of this letter is to respond to the request for additional information (RAI) identified in the NRC e-mail correspondence to UniStar Nuclear Energy, dated May 11, 2011 (Reference 1). This RAI addresses Seismic System Analysis, as discussed in Section 3.7 of the Final Safety Analysis Report (FSAR), as submitted in Part 2 of the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 Combined License Application (COLA), Revision 7.

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NRD

A schedule for the response to RAI 304 Questions 03.07.02-55, 03.07.02-58, and 03.07.02-59 was provided in Reference 2 and in Reference 3. The enclosure provides our response to RAI No. 304, Questions 03.07.02-55, 03.07.02-58, and 03.07.02-59, and includes revised COLA content. A Licensing Basis Document Change Request has been initiated to incorporate these changes into a future revision of the COLA.

Our response does not include any new regulatory commitments. This letter does not contain any sensitive or proprietary information.

If there are any questions regarding this transmittal, please contact me at (410) 470-4205, or Mr. Wayne A. Massie at (410) 470-5503.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on August 25, 2011

for Greg Gibson

Enclosure: Response to NRC Request for Additional Information RAI No. 304, Questions 03.07.02-55, 03.07.02-58, and 03.07.02-59, Seismic System Analysis, Calvert Cliffs Nuclear Power Plant, Unit 3

cc: Surinder Arora, NRC Project Manager, U.S. EPR Projects Branch
Laura Quinn, NRC Environmental Project Manager, U.S. EPR COL Application
Getachew Tesfaye, NRC Project Manager, U.S. EPR DC Application (w/o enclosure)
Charles Casto, Deputy Regional Administrator, NRC Region II (w/o enclosure)
Silas Kennedy, U.S. NRC Resident Inspector, CCNPP, Units 1 and 2
U.S. NRC Region I Office

GTG/AJF/mdf

Enclosure

Response to NRC Request for Additional Information
RAI No. 304, Questions 03.07.02-55, 03.07.02-58, and 03.07.02-59,
Seismic System Analysis,
Calvert Cliffs Nuclear Power Plant, Unit 3

RAI No. 304

Question 03.07.02-55

Because the amount of concrete cracking under combined earthquake and other loads can affect the seismic response of a structure and therefore the building design, the staff in Question 03.07.02-43 asked the applicant to provide the results of an analysis which verifies the applicant's statement that only the east and west forebay walls will crack and that the other walls and slabs remain uncracked under the applicable loading conditions which include earthquake loads. The methodology for determining the stiffness of the structure and the amount of cracked vs. un-cracked sections outlined in the applicant's response is acceptable. However, to enable the staff to understand the details and results of the analyses that are presented, the applicant is requested to provide the following additional information:

1. The response states that in Figures 1-4 cracked elements are magenta and un-cracked elements are blue. The key in the upper left hand corner of each figure is not clear, and could be interpreted to imply just the opposite. The applicant is requested to clarify which elements are cracked and which are un-cracked by providing a key which clearly identifies which is which.
2. Provide the criteria that were used to determine that a section was cracked, and the loads and loading combinations that were used for this determination.

Response

Question 1:
Figures 1 through 4 have been revised (see attached) with a color key that clearly identifies the location of the cracked elements.

Question 2:
The following criteria are used to determine if a section is cracked:

- The cracking moment is calculated using Eq. 9-8 of ACI 349-01 in conjunction with the recommendations for the calculation of the modulus of rupture (Eq. 9-9 of ACI 349-01).

- For each plate element the maximum moment is taken as the maximum of Mx and My. Note that Mx and My align with the reinforcement directions.

- If the maximum moment exceeds the cracking moment, the particular plate element is considered to be cracked.

The following load combination, consisting of the Normal Loads combined with the SSE loads, is considered for the purpose of determining whether an element is cracked:

D + F + B + L + S + H + E'

Where,

D = Dead load of the structure (includes plant loads)
F = Hydrostatic pressures representing water inside the structure

B = Buoyancy pressures acting on the outside of the structure
L = Live loads
S = Snow loads
H = Static soil pressures acting on the walls
E' = SSE accelerations resulting from the SASSI analysis

The following enveloping combinations are considered for the Normal Loads:

$N_{min} = 0.9D + 0.9F + B + 0.9H$
$N_{max} = D + F + B + 0.25L + 0.75S + H$

A maximum and minimum value is determined for each load effect induced by N_{min} and N_{max}. These values represent enveloping values for the Normal loads.

The seismic accelerations are applied separately in each of the three directions and the corresponding three analyses produce three sets of results. The results yielded by the three analyses for each load effect are subsequently combined using a summation of the absolute values.

For each load effect the SSE results are combined with the Normal loads envelopes in such a manner that the N_{min} value is decreased and the N_{max} value is increased. These results constitute minimum (NE_{min}) and maximum (NE_{max}) enveloping values for each load effect.

The maximum moments of the NE_{min} and NE_{max} envelopes are compared to the cracking moment to determine if an element is cracked.

COLA Impact

The COLA FSAR will not be revised as a result of this response.

Figure 1: Cracked Elements for SSE Analysis – Basemat

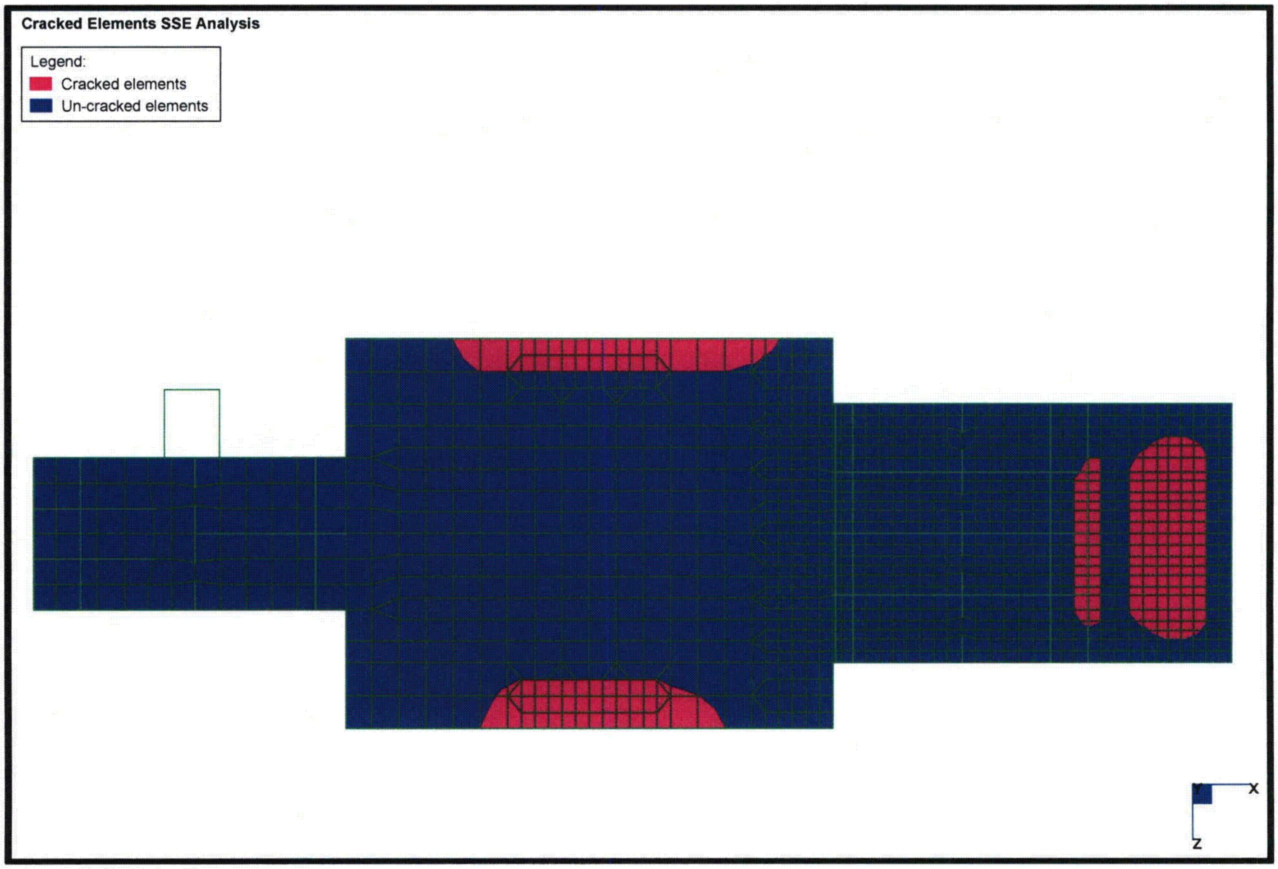


Figure 2: Cracked Elements for SSE Analysis – Forebay Walls

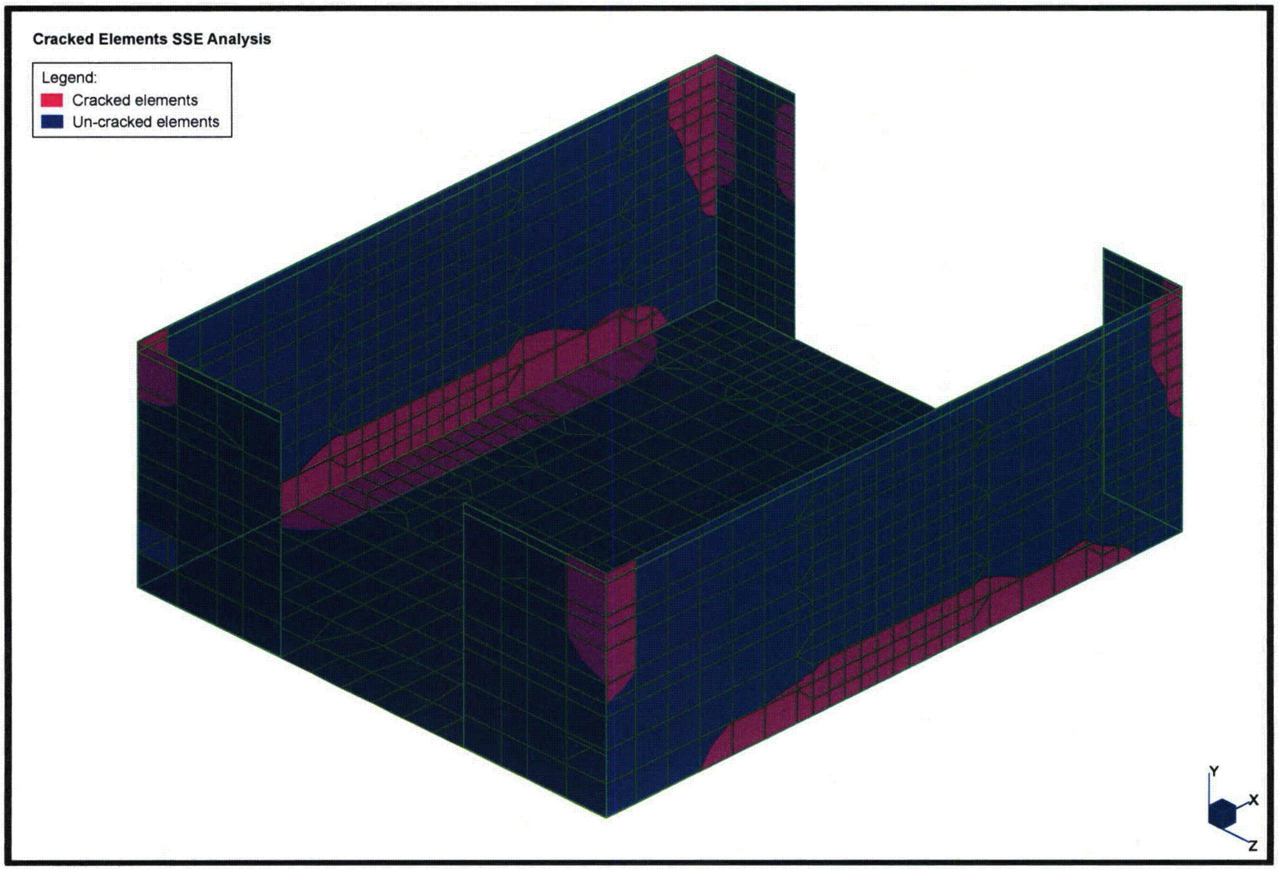


Figure 3: Cracked Elements for SSE Analysis – Pump House North-South Walls

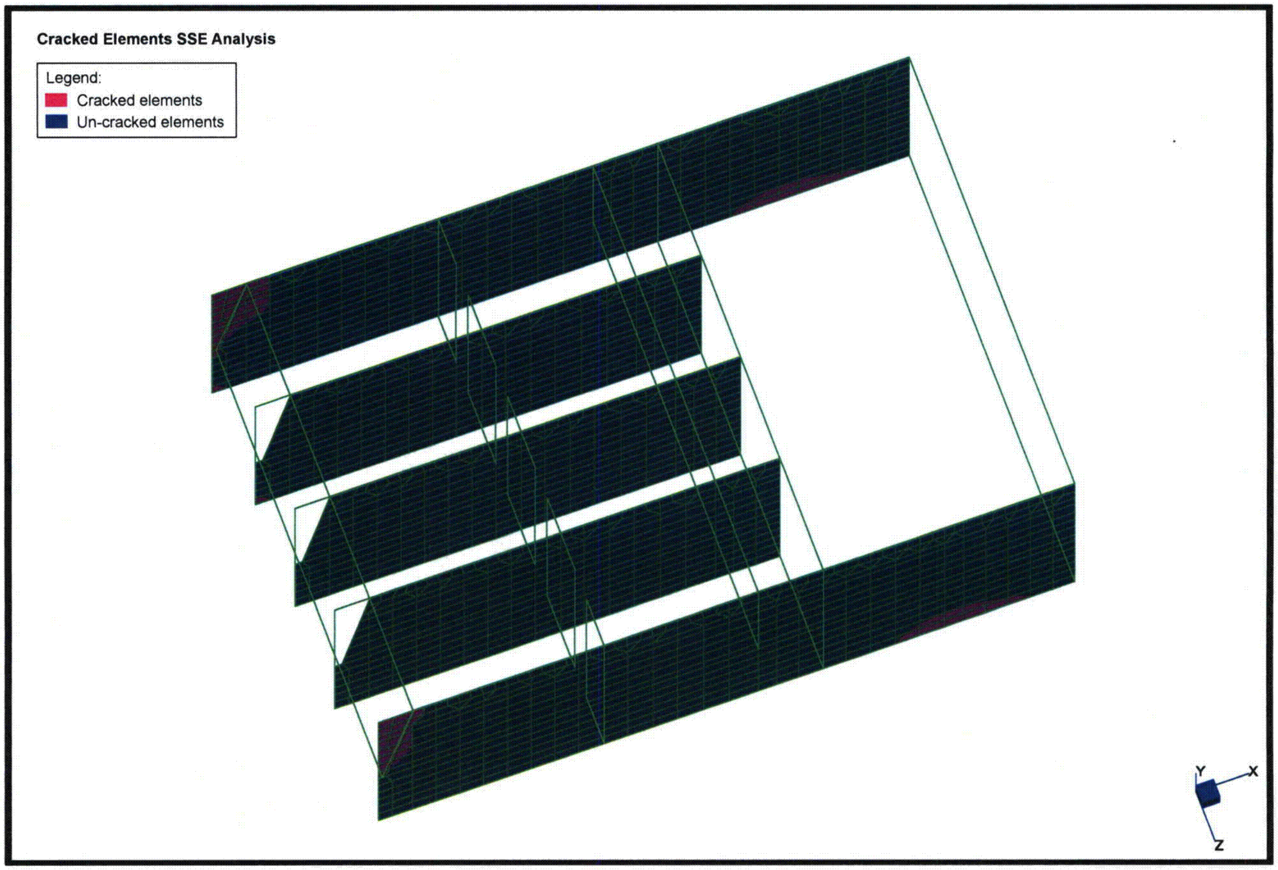
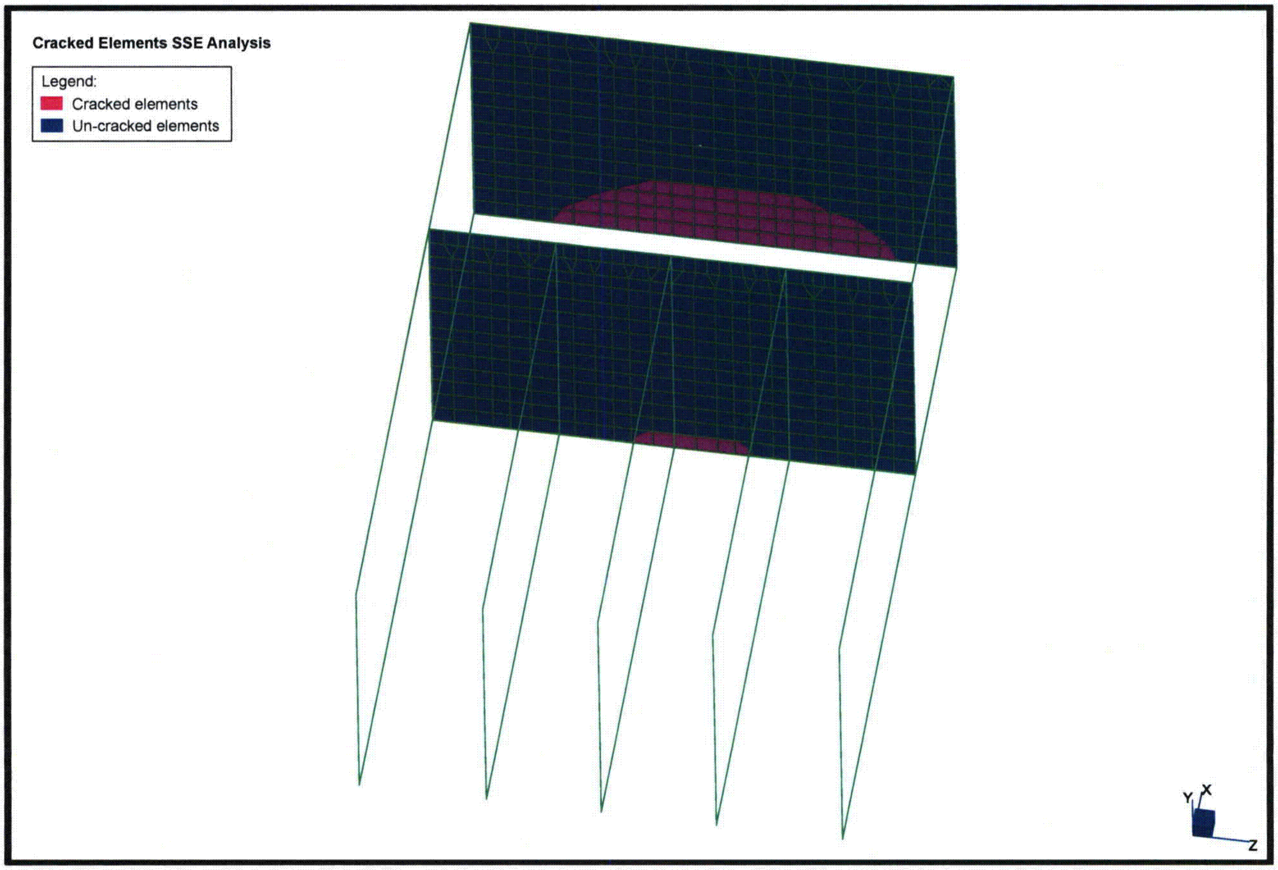


Figure 4: Cracked Elements for SSE Analysis – Pump House East-West Walls



Question 03.07.02-58

In Question 03.07.02-53, the staff asked how the results of the SASSI analysis are used to determine forces and moments within the static model for building design. The response provided by the applicant only states that absolute accelerations are used. This description does not provide information in sufficient detail for the staff to understand how results of the SASSI analysis including hydrodynamic effects were used in the static model and conclude that the structure will meet the requirements of General Design Criteria 2 for earthquake loads. The applicant is requested to describe each step used to calculate the seismic moments and forces needed for the design of the structure starting with the structural accelerations due to each direction of earthquake excitation as determined from the SSI seismic analysis.

Response

The Soil Structure Interaction (SSI) analyses are performed with an finite element model using RIZZO computer code SASSI, Version 1.3a. Each component of the earthquake acceleration time-history (x-, y- or z-direction) is considered in a separate analysis. The total acceleration in a selected global direction at a specific location in the model is determined at each time step as the algebraic sum of the values of the accelerations in the direction under consideration, induced by each of the three earthquake time-histories. The resultant time history is subsequently searched to find the maximum total acceleration in the selected direction at the location under consideration. Since the three components of the earthquake motion are statistically independent, this approach is endorsed by RG 1.92. It is noted that this approach is a modification from the previous analyses of the Common Basemat Intake Structures (CBIS), in which the SRSS method was used to obtain the maximum responses. This modification was made in order to achieve better consistency with the US EPR FSAR.

The above process is repeated for the accelerations in each of the three global directions to yield the maximum values contained in the time histories of the total accelerations in the x-, y- and z-directions, at the location under consideration. Such a set of maximum total accelerations are determined at each of the predefined locations in the model to produce results at the corners and centers of walls and floors.

This procedure is repeated for each of the three sets of soil properties (lower bound, best estimate and upper bound) to obtain three sets of maximum total accelerations at each of the predefined locations. The largest of the maximum total accelerations in each direction at each location is subsequently applied to the STAAD Pro Finite Element (FE) model.

The seismic accelerations calculated by the SSI analyses, as described above, are applied to a more detailed FE model, and these are analyzed as follows, using the STAAD Pro FE package:

1. The structure is subdivided into groups, each of which comprises a floor and its supporting walls.
2. The maximum acceleration in each of the three directions is determined for each group on the basis of the values at the predefined locations contained in that particular group.
3. Each set of maximum accelerations is applied to the walls and slab comprising the appropriate group in the static FE model.
4. The STAAD Pro FE package appropriately applies these accelerations to the masses of the walls and slab contained in each group, thus treating the accelerations as static-equivalent loads.

Seismic loads due to hydrodynamic effects are included in the analysis on the basis of the recommendations of ACI 350.3-06. This is accomplished by applying the inertia loads associated with the convective and impulsive effects as equivalent pressures to the walls that contain the water. The inertia loads associated with the convective and impulsive effects are obtained by applying the accelerations obtained from the SSI analyses to the hydrodynamic masses that idealize each of these effects in the SASSI analyses (which are calculated on the basis of the methods presented in ACI 350.3-06). These loads act in each of the horizontal directions. The hydrodynamic loads induced by the vertical accelerations are obtained as recommended by ACI 350.3-06. It is noted that the seismic loads due to hydrodynamic effects were not included in the previous analyses of the static model.

The seismic moments and forces needed for the design of the structure are obtained by conducting a separate analysis, whereby, the accelerations in the x-direction are applied simultaneously to the model in the positive sense. Following the recommendations of ACI 350.3-06, the impulsive hydrodynamic loads in the x-direction are applied simultaneously with the accelerations in the x-direction (taken as being horizontal for the purposes of this discussion). Separate analyses are carried out in a similar manner in the y- and z- directions, with the impulsive hydrodynamic loads in the y-direction being applied together with the accelerations in the y-direction (taken as being horizontal), and the hydrodynamic loads induced by the vertical accelerations applied together with the accelerations in the z-direction (vertical direction).

According to ACI 350.3-06, the convective hydrodynamic loads are not in phase with the impulsive loads and are therefore analyzed separately in the x- and y-directions.

The results obtained for the induced stress resultants (i.e. member forces and moments) from these various analyses are subsequently added using the SRSS method to obtain the design load effects. This approach is in conformance with the methods endorsed by RG 1.92.

Design values are obtained for the following load effects:

1. Bending moments (M_{xx}, M_{yy})
2. Twisting moment (M_{xy}).
3. Out of plane shear forces (V_x, V_y).
4. In-plane forces (N_{xx}, N_{yy}, N_{xy}).

These seismic load effects are subsequently combined with the stress resultants induced by the balance of the loads contained in the seismic load combination to produce the most onerous results as described below.

The seismic load combination comprises the Normal Loads and the SSE loads as follows:

D + F + B + L + S + H + E'

where

D = Dead load
F = Hydrostatic pressures to account for acting forces from water inside the structure
B = Buoyancy pressures acting on the outside of the structure
L = Live loads

S = Snow loads
H = Static soil pressures acting on the walls
E' = SSE accelerations resulting from the SASSI analysis

The following enveloping combinations are considered for the Normal Loads:

Nmin = 0.9D + 0.9F + B + 0.9H
Nmax = D + F + B + 0.25L + 0.75S + H

A maximum and minimum value is determined for each load effect induced by Nmin and Nmax. These values represent enveloping values for the Normal loads.

For each load effect, the Safe Shutdown Earthquake (SSE) results are combined with the Normal loads envelopes in such a manner that both the N_{min} value is decreased and the N_{max} value is increased. These results constitute minimum (NE_{min}) and maximum (NE_{max}) enveloping values for each load effect.

Accidental torsion is considered in a separate analysis. For a particular floor level, the accidental torsional moment is obtained as the product of the story inertia force and a lever arm equal to 5 percent of the appropriate maximum building plan dimension. The story inertia force is obtained by applying the seismic accelerations (yielded by the SSI analyses) to the mass of the story, which comprises the floor and its supporting walls. The torsional moment at a floor elevation is simulated in the analysis by applying accelerations to the Eastern and Western outer walls in such a manner that the resulting inertia forces in these walls produce a torsional moment equal to the accidental story torsional moment and the sum of these inertia forces produce a zero resultant force. Accidental story torsional moments are determined for each floor elevation, and the UHS MWIS, Forebay walls and Circulating Water (CW) Makeup Water Intake Structure (MWIS) are considered independently. The results of this analysis are combined with the minimum and maximum envelopes in such a manner that NE_{min} and NE_{max} envelopes are decreased and increased, respectively.

COLA Impact

The COLA FSAR will not be revised as a result of this response.

Question 03.07.02-59

The last paragraph on page 11 of Enclosure 2, UniStar letter UN#10-285 dated November 16, 2010, includes two sentences which state, "The skimmer walls, at the entrance of the UHS Makeup Water Intake Structure and Circulating Water Makeup Intake Structure into the Forebay Structure, have an inclination of approximately 10 degrees with the vertical, which is neglected in the finite element model. This simplification has an insignificant effect on the global mass and stiffness distribution, and is conservative for the local response of structural panels." This appears to be redundant to information provided in the last paragraph on page 12 of Enclosure 2. If this is an error, the applicant is requested to provide the corrected text.

Response:

The redundant information will be removed.

COLA Impact

FSAR Section 3.7.2.3.2 will be updated as follows:

3.7.2.3.2 Seismic Category I Structures – Not on Nuclear Island Common Basemat

The reinforced concrete basemat, floor slabs, and walls of the Common Basemat Intake Structures are modeled using plate/shell elements to accurately represent the structural geometry and to capture both in-plane and out-of-plane effects from applied loads. The finite element mesh is sufficiently refined to accurately represent the global and local modes of vibration. ~~The skimmer walls, at the entrance of the UHS Makeup Water Intake Structure and Circulating Water Makeup Intake Structure into the Forebay Structure, have an inclination of approximately 10 degrees with the vertical, which is neglected in the finite element model. This simplification has an insignificant effect on the global mass and stiffness distribution, and is conservative for the local response of structural panels.~~ The finite element model in SASSI uses a thin shell element formulation that represents the in-plane and out-of-plane bending effects. In-plane shear deformation ~~are~~ <u>is</u> accurately reproduced by the finite element mesh, while out-of-plane shear deformations are considered negligible due to the low thickness/height ratio of these walls.

The reinforced concrete basemat, floor slabs, and walls of the CBIS are modeled using thin shell elements in RIZZO computer code SASSI, Version 1.3a, to accurately represent the structural geometry and to capture in-plane membrane and out-of-plane bending. The average mesh size used in the finite element model below ground level and along the vertical direction is approximately 1.6 ft (0.5 m), based on one-fifth of the wave length at the highest frequency of the SASSI analysis. The average mesh size in the plan direction is approximately 5 ft (1.5 m), ~~a~~based on an aspect ratio of approximately 3.0.

The skimmer walls, at the entrance of the UHS Makeup Water Intake Structure and the Circulating Water Makeup Intake Structure into the Forebay, have an inclination of approximately 10 degrees with the vertical. However, these walls are modeled vertically for simplification of the finite element model. This simplification has an insignificant effect on the global mass and stiffness distribution, and on the local responses of the structural panels.