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NSD-NRC-97-5161
DCP/NRC0894
Docket No.: STN-52-003

June 2, 1997

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: T. R. QUAY

SUBJECT: STRUCTURAL OPEN ITEMS

Attached are responses to three open items related to structural issues. The issues addressed are the monitoring of the passive containment cooling water storage tank, membrane forces in the shear walls, and the types of stirrups used in the basemat slab. The open items and the status with the transmittal of this letter are tabulated below:

Item	OITS #	W Status
DSER 3.8.4.4-3	751	Confirm W
DSER 3.8.5-9	767	Confirm W
Meeting item #8, NRC March 4, 1997 letter	5029	Action N

The SSAR updates included in the responses will be included in revision 13 of the AP600 SSAR.

If you have any questions please contact D. A. Lindgren at (412) 374-4856

C L Haley for BAM

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

jml

Attachment

cc: D. T. Jackson, NRC (w/Attachment)
N. J. Liparulo, Westinghouse (w/o Attachment)

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Open Item # 751 DSER Open Item 3.8.4.4-3

DSER open item 3.8.4.4-3 states "....because a massive amount of water is to be contained in the passive containment cooling water storage tank, the COL applicant should monitor the deformation (vertical and radial) of the tank during initial filling and compare with the tank deformation predicted by calculation."

The NRC letter of March 4, 1997, "Summary of Meeting to discuss Westinghouse AP600 structural design" stated: "Post-construction testing is necessary to confirm adequacy of the PCS tank."

Westinghouse response

The design of the shield building roof and PCS tank meets the requirements of ACI 349. The design calculations have been reviewed by NRC staff during meetings in June 1995 and December 1996. Tank deformations during tank filling are small. For the design prior to the increase in PCS water inventory, the vertical displacement of the PCS tank during filling is calculated to be 0.07 inches. This will increase to about 0.09 inches for the design with the increase in PCS water inventory. Monitoring of tank deflections and comparison against predictions is not meaningful because of the small magnitude of the deflections due to the water inventory. Vertical deflections could also be caused by thermal changes and accurate measurements of the deflections due to the water inventory only would be difficult.

Post-construction testing of the PCS tank will be performed by visual inspection for signs of leakage or distress before and after filling of the tank. This is consistent with the requirements for visual inspection in ASME Section III Subsection NC for steel atmospheric and 0 - 15 psig storage tanks. For atmospheric tanks ASME requires that the tank be inspected frequently during the filling operation.

SSAR Revision

Revise subsection 3.8.4.7 as follows:

3.8.4.7 Testing and In-Service ~~Testing and~~ Inspection Requirements

The boundaries of the PCS tank and the tension ring of the shield building roof will be inspected visually for any signs of leakage or distress before and after first filling of the PCS tank.

There are no in-service testing or inspection requirements for the seismic Category I structures.

Open Item # 767 DSER Open Item 3.8.5.9

The open issue is summarized in the NRC letter of March 4, 1997, "Summary of Meeting to discuss Westinghouse AP600 structural design", item # 5, as follows:

"Horizontal Membrane Forces in Shear Walls

When the shear walls act as stiffeners to reduce the out-of-plane bending of the basemat slab (in the direction of the length of the shear walls), these walls behave like deep beams in the vertical direction and are likely to develop large in-plane horizontal tensile stresses near the bottom at the interface with the basemat. This behavior was observed in Initec Calculation No. 1010-CCC-001, Rev. O, for wall L (e.g., Element Nos. 6880, 6884, 6886, 6961, etc. where horizontal in-plane axial force A_{xx} ranges from 40 to 46 kips per foot). But, at about the same location, the horizontal in-plane axial force S_{xx} in Calculation No. 1000-S2C-031 (wall along column Line L, Areas 1/2, Group G49, see Page 354 & the associated computer output sheets) is shown as 4.456K/ft (Element No. 6, Load case 2, Seismic). It is staff's understanding that this later calculation was used in the design of walls. The discrepancy in the loads is possibly because the later calculation assumed fixed-base conditions in which the basemat cannot flex and there is no in-plane deep beam action of the shear walls in the vertical direction.

From this observation, the staff expressed a generic concern that if the wall design is based only on the fixed-base case, at certain locations, the design may not be adequate for softer, soil cases. Westinghouse agreed to examine this issue further and evaluate its effects on the wall design (see also Item 11 for the impact of this issue on the design of the basemat)."

Westinghouse Response

Horizontal membrane forces at base of walls.

The results quoted above from Initec Calculation No. 1010-CCC-001, Rev. O, for wall L are horizontal in-plane axial compression forces. These horizontal compression forces are due to the vertical compression forces in the wall and the Poisson effect of the basemat restraint. The vertical force is always compression since the basemat is free to lift off the foundation in the basemat analyses.

The results quoted above for the Initec analyses are those for the most critical dead load plus seismic load for wall L. The results quoted for the Bechtel analyses are only those due to seismic loads. The Bechtel fixed base results show the axial load is -9.761 kips/ft for dead plus seismic loads.

Additional response spectrum analyses are described below using the BSAP finite element model of the Coupled Auxiliary and Shield Buildings on a flexible base. The results of these analyses on a flexible base show larger forces at the bottom of the walls than in the BSAP fixed base analyses. There are similar horizontal compression forces close to the basemat for dead plus SSE loads. The magnitudes are a little lower than in the Initec analyses since there is greater refinement in this portion of the Initec basemat model than in the BSAP model. The BSAP results show that the forces due to dead and seismic loads are about equal and that there is only small tension when the seismic load is in the opposite direction to the dead load.

Effect of flexible foundation

Response spectrum analyses have been performed using the coupled Auxiliary and Shield Buildings on a flexible base. The model is the same as was used for the fixed-base hard rock site response spectrum analyses described in SSAR subsection 3.2.2.1.1 except that plate elements representing the basemat and horizontal and vertical springs are added to represent the flexibility of the subgrade. As in the fixed-base hard rock site response spectrum analyses, the lateral support provided by the embedment below grade is not considered. The stiffness of the springs is based on 520 kips/cubic foot as in the Nuclear Island basemat analyses. The damping of the soil springs is 20 percent.

The response spectrum analysis performed for the flexible base overestimates the seismic response because of the conservative treatment of soil structure interaction. It provides the relative distribution of loads to the various shear walls when the plant is located at a soil site. Adjustment factors are applied so that the overall forces in the structure match corresponding results from the SSI analyses performed previously using SASSI.

The principal quantities to match between the results from the three-dimensional finite element model on the flexible base and the rigorous SSI analyses are the overturning and shear at the base of the walls (Elevation 66' 6"). This is accomplished by establishing adjustment factors as described below. These are then applied to the results of the flexible base response spectrum analyses.

- Overturning

  Vertical subgrade pressures at the bottom of the basemat are used as a measure of the base overturning. The base pressures at the corners of the nuclear island obtained from the flexible base response spectrum analyses are compared to the base pressures obtained by applying the loads from the SASSI analyses to a rigid base mat. The adjustment factors are calculated for each horizontal and vertical direction as the ratio of the subgrade pressures obtained from the rigid base mat assumptions divided by the response spectrum analysis results of the flexible base model.

- Shear

  The adjustment factor based on shear is obtained by dividing the total shear in each direction at Elevation 66'-6" from the fixed base response spectrum analysis by the results from the flexible base response analysis results. In order to envelope the SASSI responses, the factor is further adjusted by the SSI factor used in the fixed base response spectrum analysis.

As confirmation for the above analyses, the shear and moment were also checked higher up in the structure at the base of the Shield Building roof, Elevation 241' 0". The adjustment factor is the ratio of the shear force at Elevation 241' 0" from the fixed base analysis results divided by the shear force at Elevation 241' 0" from the flexible base analysis. The factor is further adjusted by the SSI factor used in the fixed base response spectrum analysis .

Seismic loads due to 5% accidental torsion are added to the adjusted flexible base results. In-plane forces in the walls and slabs from the flexible base analysis are higher than those from the fixed base analysis at some locations. The walls and slabs in the Auxiliary and Shield Buildings are designed for the envelope of the forces and moments obtained from the fixed base and flexible base response spectrum analyses results.

Openings in Shearwalls

Walls on Column Lines J and K on the north side of the Auxiliary Building contain a number of openings which are not explicitly modeled in the ANSYS model used in the analyses of the nuclear island basemat or in the BSAP 3D model used in the response spectrum analyses. Each of the openings is small enough that it was excluded from the original models. However, the proximity of the openings to other openings could affect the distribution of loads and the stiffness of the walls. An investigation was performed to determine how the unmodeled openings affect the load distribution in the structure. The BSAP 3D model was modified to consider the additional openings. Then the two BSAP 3D models, one with openings and another without openings, were analyzed by the following methods:

- By response spectrum analyses of the fixed-base case.
- By static 1.0g North-South accelerations applied to the fixed-base models.
- By static 1.0g North-South accelerations applied to the flexible-base models.

The results show that the effects of the openings are local. At the levels of the additional openings themselves, Elevation 100' to Elevation 135'-3", there is redistribution of forces due to the openings. These effects are considered in the design of the shear walls. In areas away from the openings, and especially at the basemat level, the effects are minor.

SSAR Revision

Revise SSAR subsection 3.7.2.1.1 as shown below.

3.7.2.1.1 Response Spectrum Analysis

Response spectrum analyses, using computer program BSAP (Reference 7), are performed to obtain the seismic forces and moments required for the structural design of the auxiliary building, the shield building, and the containment internal structures on the nuclear island. The response spectrum analyses consider modes up to 33 hertz using the double sum modal combination method, and consider high frequency responses using the procedure given in Appendix A to SRP 3.7.2, Revision 2.

The analyses are performed using the three-dimensional, finite element models of the coupled shield and auxiliary buildings and the containment internal structures developed and discussed in subsection 3.7.2.3. Figure 3.7.2-1 shows the finite element model of the coupled shield and auxiliary buildings without the shield building roof stick model. The finite element model of the containment internal structures is shown in Figure 3.7.2-2. In addition, two typical wall sections of the coupled shield and auxiliary buildings are presented in Figure 3.7.2-3.

Response spectrum analyses are performed ~~only~~ for the hard rock site where the soil-structure interaction effect is negligible, as described in Appendix 2B. Th~~erefore, the~~ response spectrum analyses are performed using the fixed-base, three-dimensional, finite element models. The support provided by the embedment below grade is not considered in these response spectrum analyses. ~~The in-plane forces obtained from the analyses are used for the design of floors and walls.~~

A comparison of the member forces and moments obtained in the three-dimensional analyses of the lumped-mass stick models, Tables 3.7.2-11 through 3.7.2-13, shows that the hard rock profile does not always govern design of the nuclear island structures. In cases where other design soil profiles give higher element forces than the hard rock profile, the in-plane forces obtained from the response spectrum analyses of the finite element models for the hard rock site are increased by a scaling factor. The scaling factor, at a given plant elevation, is equal to the ratio of the largest three-dimensional stick model element force over the three-dimensional stick model element force for the hard rock profile.

Response spectrum analyses are also performed using the Coupled Auxiliary and Shield Buildings on a flexible base. The model is the same as that used for the fixed-base hard rock site response spectrum analyses described above, except that plate elements representing the basemat and horizontal and vertical springs are added to represent the flexibility of the subgrade. As in the fixed-base hard rock site response spectrum analyses, the support provided by the embedment below grade is not considered.

The response spectrum analysis performed for the flexible base overestimates the seismic response because of the conservative treatment of soil structure interaction. It provides the relative distribution of loads to the various shear walls when the plant is located at a soil site. Adjustment factors are applied so that the overall forces in the structure match corresponding results from the SSI analyses performed previously using SASSI.

The envelope of the in-plane forces obtained from the response spectrum analyses on the fixed base and on the flexible base is used for the design of floors and walls.

Response spectrum analysis of the fixed-base nuclear island lumped-mass stick model is discussed in subsection 3.7.2.2.

Revise second paragraph of subsection 3.8.4.4.1 as follows:

The seismic Category I structures are reinforced concrete and structural module shear wall structures consisting of vertical shear/bearing walls and horizontal slabs supported by structural steel framing. In-plane seismic forces are obtained from the response spectrum analysis of the three dimensional finite element ~~fixed-base~~ models described in Table 3.7.2-14. These results are modified to account for soil structure interaction and accidental torsion as described in subsection 3.7.2. Also evaluated and considered in the shear wall and floor slab design are out-of-plane bending and shear loads, such as live load, dead load, seismic, lateral earth pressure, hydrostatic, hydrodynamic, and wind pressure. These out-of-plane bending and shear loads are obtained from the response spectrum analyses supplemented by hand calculations. The exterior walls of the seismic Category I structures below the grade are designed to resist the worst case lateral earth pressure loads (static and dynamic), soil surcharge loads, and loads due to external flooding as described in Section 3.4. Appendix 2C describes the seismic analyses used to calculate the lateral earth pressures on the exterior walls below grade. The exterior walls are also designed for full passive earth pressure which is utilized in the sliding evaluation described in subsection 3.8.5.5.3. Figure 3.8.4-2 shows typical shear walls and the arrangement of the reinforcing steel. Figure 3.8.4-3 shows typical reinforcing for the slabs.

Add flexible base model after row describing fixed base model in Table 3.7.2-16 as follows:

3D finite element, fixed base models, coupled Aux/Shield buildings and Cont. internal structures	Response spectrum analysis	BSAP	SRSS	Double Sum
3D finite element, flexible base model, coupled Aux/Shield buildings	Response spectrum analysis	BSAP	SRSS	Double Sum

Open Item # 5029

The open issue is identified in the NRC letter of March 4, 1997, "Summary of Meeting to discuss Westinghouse AP600 structural design", item # 8, as follows:

"Type of Stirrups to be Used in the Basemat Slab.
Westinghouse intended to use stirrups with 90-degree bends and provides justification on the basis of some discussion in the code commentary. The staff expressed a concern that the code provisions are not being interpreted by Westinghouse conservatively, and that, considering the multitude of uncertainties that Westinghouse did not or could not consider from practical considerations, the use of 135-degree bent stirrups is preferable."

Westinghouse response

Shear in the nuclear island basemat is evaluated in accordance with paragraph 11.5 of ACI 349-90. In a few bays shear reinforcement is required as shown in SSAR Figure 3.8.5-3 (sheet 5 of 5). This shear reinforcement consists of # 7 bars with a standard hook as required by paragraph 12.13.2.1 of ACI 349-90. The standard hook is defined in paragraph 7.1.2 of ACI 349-90 as a "90-deg bend plus 12 d_b extension at free end of bar".

The requirements for shear reinforcement in ACI 318-95 are similar to those in ACI 349-90 except for those structural elements covered by Chapter 21 of ACI 318-95. Commentary paragraph 12.13.2.2 states: "A 135-deg or 180-deg hook is preferred, but a 90-deg hook may be used provided the free end of the 90-deg hook is extended the full 12 bar diameters as required in 7.1.3."

Chapter 21 contains special requirements for design and construction of reinforced concrete members of a structure for which the design forces, related to earthquake motions, have been determined on the basis of energy dissipation in the nonlinear range of response. Paragraph 21.1 of ACI 318-95 defines a seismic hook as a hook having a bend not less than 135 deg with a six diameter extension. A cross tie is required to have a seismic hook at one end and a hook not less than 90 deg with at least a six diameter extension at the other. Seismic hooks are required in paragraph 21.3.3 for transverse reinforcement in flexural members of frames particularly close to the ends of the member where non-linear cyclic deformation is expected in a seismic event.

The nuclear island basemat is loaded in the upward direction by soil bearing reactions due to dead and seismic conditions. The loading is in a single direction since the basemat can lift off the soil. Thus, the cyclic conditions considered in the design of flexural frame members in paragraph 21.3.3 of ACI 318 do not occur even if the bearing reactions are higher than the dead plus SSE loads for which the basemat is designed. In addition, Chapter 21 addresses frame members but does not address slab design. The provisions of Chapter 21 are not applicable to the nuclear island basemat.

As stated in ACI 318-95 and in the NRC staff observation, a 135-deg or 180-deg hook is preferred. Such a detail is difficult to construct and is not consistent with normal construction of a slab where the stirrups are placed after placement of the top and bottom reinforcement mats. The 90-deg hook included in the AP600 meets the requirements of the code and provides adequate ductility for the nuclear island basemat.

SSAR Revision: None