DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

April 22, 2008

MEMORANDUM FOR: J. K. Fortenberry, Technical Director

COPIES: Board Members

FROM: D. Andersen

SUBJECT: Waste Solidification Building, Structural and Geotechnical Review

This report documents a structural and geotechnical review by the staff of the Defense Nuclear Facilities Safety Board (Board) of the Waste Solidification Building (WSB) to be constructed at the Savannah River Site (SRS). WSB is being designed by the Washington Savannah River Company (WSRC) and is expected to receive a combined Critical Decision-2/3 approval from the Department of Energy in early October 2008. The staff's review was conducted on February 25, 2008, by teleconference and on February 27–28, 2008, by site visit. The Board's staff will be following up to determine whether the project has addressed the issues noted by the staff during the review in newly revised calculations and drawings.

Project Background. The preliminary design for the WSB project was completed in 2003, and was placed on hold because of replanning efforts at the Mixed-Oxide Fuel Fabrication Facility (MFFF) and the Pit Disassembly and Conversion Facility (PDCF). The WSB facility was initially a line item under the PDCF project, but has since become a separate project. Following this change, design activities for WSB were reinitiated.

The WSB is part of the Plutonium Disposition Program, which will convert excess plutonium in the defense complex to commercial fuel rods. WSB will process high- and low-activity liquid wastes received from MFFF and PDCF. All three facilities will be constructed in the F-Area at SRS. The liquid waste processing includes neutralization, evaporation, and solidification (cementation). In addition to liquid waste processing, the facility will have an analytical laboratory and waste storage area. The facility will be Hazard Category 2 and is being designed to a seismic demand based on Nuclear Regulatory Commission Regulatory Guide 1.60 (for consistency with MFFF and PDCF). This seismic motion is scaled to 0.2 g acceleration and envelopes the SRS Performance Category 3 response spectra. The current facility design is divided into two main processing areas for high-activity and low-activity liquid waste. Most of the material-at-risk will be generated by MFFF and processed in the high-activity process area.

Geotechnical Review. The Board's staff held a teleconference with project representatives to discuss the staff's geotechnical review of WSB. The focus of the discussion was on the development of design dynamic settlement profiles.

Issues concerning dynamic settlement have recently been raised for other design projects at SRS, including PDCF and the Salt Waste Processing Facility (SWPF). Dynamic settlement at the surface can result from the compression or collapse of existing pockets of soft soil at SRS, commonly referred to as "soft zones." The mechanism by which soft zones collapse and the means by which the settlement propagates to the ground surface have been the subject of many discussions between the Board's staff and SRS personnel.

WSB project personnel claim they are using the design settlement profile for the PDCF project. In a letter dated September 26, 2006, the Board indicated that the design settlement profile for PDCF was acceptable. However, the staff's review of the geotechnical report for WSB indicates that the magnitude of the design settlement profile due to the soft zones for the project (2.8 inches) is less than that used in the PDCF design (3.4 inches). In addition, the Board's September 26, 2006, letter noted that the methodology and analytical approach used to derive the soil settlement profile for PDCF had several shortcomings and that the resulting design settlement profile was only acceptable because of conservatism used by that project. To address the shortcomings raised by the Board, the site is currently working to develop an appropriate methodology to analyze soft zones. These shortcomings have not been addressed in the geotechnical report for WSB or reflected in the structural design. Further, the Board's staff noted the following issues concerning dynamic settlement for WSB that make it questionable to apply the PDCF design settlement profile to WSB:

- The limited number of site investigations below WSB is not adequately reflected in the geotechnical uncertainties. For example, few site investigations were performed below the wall lines of the facility as compared to PDCF.

- The WSB project's use of a 7.6 foot thick soft zone as the bounding thickness is not justified. Soft zones thicker than this have been found in proximity to the WSB site.

- Considerable uncertainty exists in predicting the angle of settlement propagation, the compressibility of the soft zones, the thickness of these zones, and their shape. Each of these parameters impacts estimates of dynamic settlement.

- Post-seismic liquefaction settlement was calculated with older SRS cyclic resistance ratio curves instead of curves published more recently for the site.

The Board's staff, together with an outside expert, performed its own evaluation of geotechnical data for WSB and concluded that a dynamic settlement with a magnitude of approximately 4 to 5 inches would be more reasonable given the uncertainties involved.

Structural Design Review. During the on-site portion of its review, the Board's staff received the results of structural evaluations for WSB. One of the main issues raised by the staff at that time was that the structural design package lacked cohesion; most calculations were not clearly linked to one another. This shortcoming of the structural design package can be attributed to the restructuring of the project. Many of the calculations were developed piecemeal at different times during the project, and thus were challenging to follow. Project personnel told the Board's staff that these calculations are being redone to explain the structural design of WSB more clearly. The structural review performed by the Board's staff focused on the facility configuration and on how the structure was analyzed. The staff will review the newly revised structural calculations as they become available.

Structural Overview—WSB is a single-story, reinforced concrete structure with a height of 35 ft and base dimensions of 165 ft by 190 ft. The basemat of the structure is designed to be 3 ft thick, the roof 9 in. thick, and the walls 18 in. thick. Since its layout is open and only a single story tall, the facility is relatively light for the size of its footprint. By comparison, the SWPF structure will have a footprint of 136 ft by 235 ft (a base area only 2 percent larger than that of WSB) and will weigh roughly three times as much as WSB.

The main design feature the Board's staff questioned was the roof truss supporting the ceiling slab. The current design calls for the 9 in. roof slab to be supported by metal trusses. These trusses will be simply supported in wall pockets; however, their current design does not call for them to be joined compositely with the ceiling slab. The Board's staff believes that this lack of composite action creates a major interaction hazard. Since the adequacy of the wall pocket supports was not evaluated, the Board's staff suggested that the slab and trusses be designed as composite features. Project personnel verbally accepted this suggestion.

Differential Settlement Analysis—Given the light weight of WSB, differential settlement loading on the structure is less severe as compared with SWPF. When a differential settlement is placed under the footprint of a facility, it must bridge over the imposed void. The loads in the facility will be directly proportional to the weight spanning the void; the differential settlement loads for WSB will thus be far below those of SWPF. The differential settlement case was analyzed using the ANSYS finite element software; this detailed model used the nonlinear SHELL181 element in its formulation. The SHELL181 multilayer element can calculate outer face and inner face strains in bending; this element differs from a solid finite element since it is connected to its neighboring elements on only one plane. In the analysis, if either face is determined to reach the cracking strain of concrete, it is modified in the next analytical iteration to have cracked concrete properties.

The WSRC design team analyzed the facility for both a design basis 3.8 in. settlement case and a more severe 7.6 in. beyond design basis case; the latter analysis showed that additional rebar in the 3 ft basemat could accommodate the beyond design basis loads. Project representatives do not believe adding additional rebar is warranted. These results demonstrated that the building is not highly sensitive to differential settlement because of its light weight;

however, the Board's staff does not believe that the 7.6 in. case should necessarily be treated as a beyond design basis event given the geotechnical uncertainties involved. The staff urged that an attempt be made to quantify the settlement that the current design could withstand beyond the design basis settlement of 3.8 inches. In addition, given the complexity of the SHELL181 element formulation, the staff suggested that a linear elastic analysis be performed and that the impact of element nonlinearity on the model results be quantified.

Dynamic and Static Analysis—A finite-element model of WSB was created using the computer software System for Analysis of Soil-Structure Interaction (SASSI) to determine in-structure dynamic loadings. Three soil cases and a hard-rock case were analyzed with this model. The three soil cases were the lower bound, best estimate, and upper bound anticipated soil conditions; the hard-rock case was equivalent to a fixed-base condition. The analysis used cracked concrete material properties for analysis of soil-structure interaction (SSI). This assumption was conservative since the use of uncracked properties would drive fundamental frequencies of the building and walls to less demanding regions of the design response spectra. The soil conditions were overstrained in the analysis; however, since these results were conservatively enveloped with the fixed-base case, the effects of the overstraining are negligible. Typically, the strain-dependent properties for SSI are based on site response calculations that convolve the bedrock ground motion up through the soil. By contrast, the choice was made to deconvolve the surface ground motion, which resulted in minor overstraining of the soil.

After the SSI analysis was performed, dynamic SSI loads were applied statically to another finite-element model created with the software GT Strudl. The in-plane loads were directly applied from SSI output, while uniform 1 g acceleration was applied out-of-plane. Additionally, the concrete walls were conservatively evaluated out-of-plane as one-way stripes; accounting for the two-way action of a wall is more realistic and produces lower demands. The SSI results showed that out-of-plane accelerations in a wall can vary from 1.4 g at the center span to 0.2 g at the edge of a wall span, and thus a 1 g load applied uniformly would be conservative. Although the roof trusses were not originally planned to act integrally with the roof slab, the roof was analyzed as composite in the SSI calculation. The roof design was altered to act as composite when this was pointed out by the Board's staff. The composite design is more robust and is a better design feature for this facility. The Board's staff believes that the SSI analysis conservatively estimates dynamic demands on the WSB facility; the issue of the differential settlement analysis, however, still needs to be resolved.