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Implementation of Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks and Appurtenances

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Abstract

In the fall of 1992, a draft of the Seismic Design and Evaluation Guidelines for the Department of Energy (DOE) High-level Waste Storage Tanks and Appurtenances was issued. The guidelines were prepared by the Tanks Seismic Experts Panel (TSEP) and this task was sponsored by DOE, Environmental Management. The TSEP is comprised of a number of consultants known for their knowledge of seismic ground motion and expertise in the analysis of structures, systems and components subjected to seismic loads. The development of these guidelines was managed by staff from Brookhaven National Laboratory, Engineering Research and Applications Division, Department of Nuclear Energy.

This paper describes the process used to incorporate the Seismic Design and Evaluation Guidelines for the DOE High-Level Waste Storage Tanks and Appurtenances into the design criteria for the Multi-Function Waste Tank Project at the Hanford Site. This project will design and construct six new high-level waste tanks in the 200 Areas at the Hanford Site. This paper also discusses the vehicles used to ensure compliance to these guidelines throughout Title 1 and Title 2 design phases of the project as well as the strategy used to ensure consistent and cost-effective application of the guidelines by the structural analysts. The paper includes lessons learned and provides recommendations for other tank design projects which might employ the TSEP guidelines.

Introduction: A project is underway to design and construct a number of underground high level waste storage tanks at the Hanford Site. These tanks will have a nominal capacity of 1,000,000 gallons and be of a double-shell design. Each underground double-shell tank consists of two concentric structures (See Figure 1). The inner structure is constructed of welded stainless steel plate. This completely enclosed tank, normally referred to as the primary tank, is comprised of a cylindrical shell with a gently sloped bottom, an elliptical domed roof, and a torus-shaped upper and lower knuckle. The outer structure is constructed of reinforced concrete. This structure, normally referred to as the secondary concrete structure, consists of a cylindrical shell with a gently sloped bottom and an elliptical domed roof, and a torus-shaped upper and lower knuckle. The secondary concrete structure is lined with a steel liner that extends along the bottom, lower knuckle, sides, and upper knuckle of the secondary concrete structure to the upper knuckle of the primary tank. The primary tank dome and the secondary liner walls are structurally attached to the secondary concrete structure. There is no structural attachment between the primary tank and the secondary liner. The primary tank is located within the secondary concrete structure and is separated from the bottom of the secondary concrete structure and liner by an insulating/supporting pad and from the sides of the secondary concrete structure and liner by an annular air space. The dome of the primary tank is attached structurally to the dome of the secondary concrete structure.

The primary tank is designed to contain the radioactive liquid waste and to sustain hydrostatic, hydrodynamic, and thermal loads. The secondary concrete structure is designed to sustain all soil loadings, dead loads, live loads, seismic loads, and loads caused by temperature gradients between the liquid wastes and surrounding soil. The secondary concrete structure provides lateral seismic support for the top of the primary tank. The liner of the secondary concrete structure is designed to safely confine any leakage that might occur from a potential failure of the primary tank. These waste tanks typically are built in clusters and maintained in an area called a "tank farm." A tank farm comprises a group of tanks separated by a soil barrier.

In 1991 the Department of Energy (DOE) Environmental Management (EM) contracted six consultants to prepare a set of guidelines for the design and evaluation of underground high level waste tanks due to seismic loads. These consultants include Dr. Kamal Bandyopadhyay from Brookhaven National Laboratory, Dr. Robert Kennedy from Robert Kennedy Associates, Dr. Allen Cornell from Stanford University, Dr. Andy Veletsos from Rice University, and Drs. Charles Miller and Carl Costantino from City College of New York. They are normally referred to as the DOE Tank Seismic Experts Panel (TSEP). This effort was directed by Dr. Howard Eckert representing DOE-EM. In January 1993, their efforts were compiled and documented in a Brookhaven National Laboratory (BNL) Report BNL 52361, "Seismic Design and Evaluation Guidelines for the Department of Energy High-Level Waste Storage Tanks and Appurtances."

The W236A Project adopted these guidelines for the seismic design of the new tanks. The following discussion describes the process whereby these seismic guidelines were formally integrated into the design media and implemented during the Title 1 and 2 design activities.

Discussion: Since the TSEP Guidelines focus only on the seismic design of underground waste storage tanks and the Project was beyond the conceptual design stage when these guidelines were issued, a method was needed to integrate the TSEP Guidelines into the design media so as to minimize the impact on the tank design. The project functional design criteria and conceptual design report had already been completed using approved Site design criteria and preliminary design codes and standards selected for the major double shell components. A strategy to incorporate the TSEP guidelines was devised which would have the least impact to the project and yield deliverables which would improve the overall efficiency of the current design process as well as expedite future efforts to design and construct underground double shell waste tanks anywhere in the DOE complex. This strategy included the development of four documents, i. e., Design Basis Synthesis Document, Design Construction Codes and Standards Document, Site Specific Design Loads and Criteria Document, and a Desktop Design Analysis Procedures Document. These documents are described below:

Design Basis Synthesis Document: Since the TSEP guidelines just addressed the methods to determine the response of the double-shell tank components to seismic loads and the project functional design criteria was already approved. It was determined that an effort should be undertaken to compile all of the structural design requirements from component design codes, Site specific design requirements, TSEP guidelines, DOE Order and Standards, and pertinent criteria references into one document. The goal of this task was not only to compile and document all of the structural analysis criteria pertaining to design of tanks but also to reconcile any differences in requirements which might surface during its preparation. The Design Basis Synthesis Document in its final form does in fact include an integrated description of all the requirements and guidelines used for the structural design and code evaluation of the new underground tanks as well as the underground piping. It includes sections on historical analyses of existing double shell tanks at Hanford, design codes and standards, loading conditions and sequences, tank materials and properties, stress analysis methods, acceptable load combinations, influence of construction loads, and applicable acceptance criteria. Another important feature included in this document is commentary describing the rationale used to select criteria where voids occurred and when discrepancies existed among the various requirements.

The Design Basis Synthesis Document was then forwarded to EQE Consultants for review and comment. All comments were resolved to the satisfaction of both parties and formally documented.

Design Basis Codes and Standards Document

In order to ensure that the staff preparing the Design Basis Synthesis Document had accurate information regarding the appropriate component design/ construction codes, an effort was undertaken to prepare a Design Basis Codes and Standards Document. This task included documenting the rationale used to select the appropriate design/construction code for the major components of the new double-shell tanks from all possible candidates. It also included establishing code boundaries and providing the basis for resolving code jurisdictional issues, when needed. The results of this task are summarized below according to component:

Primary Tank

It was determined that the primary tank would be designed and constructed per ASME Section III, Division 1, Subsection NC-3900. All vessel joints will be full penetration butt welded joints. All vessel welds will be 100 percent radiographed. A certified design specification shall be prepared by the owner, and a certified design report shall be provided by an authorized N Certificate Holder as required by ASME Section III, Division 1, NC-3900.

The primary tank will have a detailed stress evaluation performed for specified loading conditions using ASME Section III, Division 1, NC-3200. The basic allowable stress intensity values taken from ASME Section II, Part D, Subpart 1, Tables 1A, 1B, and 3, shall be used (it is important to note that Tables 1A, 1B, and 3 provide basic maximum stress allowables that are lower than the normal NC-3200 stress-intensity allowables given in Tables 2A, 2B, and 4). Secondary stresses shall be evaluated to the rules of ASME Section III, Division 1, Appendix XIII. A fatigue evaluation, if required, shall be performed to ASME Section III, Division 1, Appendix XIV.

The code boundaries of the primary tank will consist of the following:

1) The bottom of the tank (including the thickened section and centering post over the central air-distribution chamber), the lower knuckle, the side walls, and the steel tank dome.
2) The dome nozzles up to and including the first weld bevel or flange face beyond the attachment of the nozzle to the dome (includes the riser weld to the dome steel and/or to reinforcing plates attached to the dome).
3) Welds for the nozzle anchor studs, but not the stud itself. However, the stud material shall be compatible with the nozzle material.
4) Nozzle reinforcement plates (includes the weld to the dome steel and to the nozzle.
5) The dome anchor stud welds, but not the stud itself. However, the stud material shall be compatible with the primary tank dome steel.
6) The seal weld that attaches the flashing at the interface between the secondary liner and the primary tank.
7) The welds attaching any other item, e.g., equipment anchors, instrumentation attachments, pipe supports.
8) Material for structural pressure retaining attachments shall meet NC-2000 material requirements.
9) Material for nonstructural attachments shall be compatible with the tank steel.

The effect of deformation of the dome of the secondary concrete structure shall be treated as a secondary displacement-controlled strain on the primary tank.

Secondary Liner

The secondary liner shall be designed and constructed in accordance with the rules of ASME, Section III, Division 2, CC-3000. The liner must accommodate the deformation of the secondary concrete structure without loss of leak-tight integrity. The lower knuckle region of the liner, if it is not backed by the concrete, shall be designed to ASME Code, Section

III, Subsection NC (same as the primary tank).

The code boundaries of the secondary liner consist of the following:

1) The bottom of the liner, the lower knuckle, the side walls, and the upper knuckle of the liner.
2) The annulus nozzles up to and including the first weld bevel beyond the attachment of the nozzle to the liner steel (includes the riser weld to the liner steel and/or to reinforcing plates attached to the liner).
3) Welds for the liner and nozzle anchor studs, but not the stud itself. However, the stud material shall be compatible with the liner material.
4) Welds attaching any other item, e.g., equipment anchors, instrumentation attachments, pipe supports.
5) Material for pressure retaining attachments shall meet CC-2200 material requirements.

Secondary Concrete Structure, Base Mat, and Insulating/Supporting Pad

The reinforced concrete structure including the reinforced concrete base mat and the insulating/supporting pad will be designed and constructed per ACI-349. Time- and temperature-dependent concrete properties shall be considered in the design analyses. The effects of concrete cracking, temperature gradient, and time-dependent variations of temperature distribution shall be considered.

The primary steel dome and the secondary liner shall be ignored in the analysis for strength contributions to the secondary concrete structure.

The technical rationale for selection of final concrete properties used in design and analysis shall be fully documented.

The ACI-349 requirements shall also apply to all embedments, anchor studs, reinforcing bar, and riser reinforcements not considered either part of the ASME coded primary tank or secondary liner or part of the piping or ventilation systems.

<u>Interaction</u>

The analysis of the secondary concrete structure shall be separated from the analysis of the primary tank steel dome and from the analysis of the secondary liner. The loads (deformations) imparted to the primary tank steel dome and to the secondary liner by the secondary concrete structure shall be treated as superimposed component loads as allowed by the ASME Code, Section III, paragraph NC-3111, and Appendix B, paragraph B-2121. Detailed evaluation of the composite dome and the composite wall shall be conducted to determine the strains and deformations in the primary tank steel dome and the secondary liner and to determine the demand on the anchor studs which will be evaluated to the requirements of ACI 349.

The Design Basis Codes and Standards Document was then forwarded to independent third party reviewers for comments. Comments were resolved to the satisfaction of both parties and documented accordingly.

Desktop Design Guidelines

This task included further developing the design basis criteria and commentary of the Design Basis Synthesis Document into structural analysis procedures ensuring compliance to the project design media. Essentially, this document represents the "How-To" for design of the tanks. The effort expended during its preparation resolved issues dealing with modelling, sequence of load application, software selection and linking, definition of constants, justification of analysis assumptions, methods for soil structure interaction on thermal creep analyses etc.

Since many of the DOE Standards were evolving during advanced conceptual and preliminary design phases of the project, it was of strategic importance to go through-the-motions of the analyses and document the basis for all of the technical decisions together with all of the data, load factors, and constants before the analysis of records was initiated. This also allows the oversight organizations to review the analysis approach before reviewing the design analysis of record, and therefore minimizes the interruptions during this task.

Some of the more important issues which were resolved during this task which then allowed the design analysis to proceed fairly smooth are discussed.

Since a number of sources of loading had to be addressed and most loads affect the three major components due to the composite nature of the double-shell tank, an analysis/modeling strategy had to be developed. This strategy used various finite element models, analysis software, pre and post processors, and computer aided design software to generate the models, complete discrete analysis of specific components, communicate information among models, and combine results. Codes used were COSMOS, ANSYS, SASSI, ABACUS, etc.

Embodied in this effect was the selection of element types, boundary conditions, spring rates, material constants, constraint equations, creep laws and methods for applying loads.

Once the analysis strategy was finalized, it was necessary to define a sequence of analytical tasks. Since each step of the sequence described the evaluation of interest, software to be used, input required, and output expected, it was necessary to construct a network of software routines in order that the output files from one piece of software were properly configured to be accepted as input files for the following evaluation by another software package. As this network of software communication links was being prepared, it was determined to utilize the Computer Aided Design (CAD) database of the key geometric points as the basis for generating the finite element models for the analytical software. Therefore, the structural analyses models are based on project controlled CAD files. As the drawings are revised, a decision is made as to the impact to the design analyses and, if required, finite element models are revised and analyses updated accordingly. This method ensures real time access to the current design configuration by designers and analysts alike.

Finally another advantage in the development of a desktop procedure is the identification of required data or analysis methods before they are needed for the analysis of record. This gives the Project time to compile all of the analytical prerequisesties, prepare plans for acquisitions, identify costs, and prioritize needs based on sensitivity studies, rather than treating each with the same importance.

Site Specific Design Loads and Criteria Document

The development of the above three documents facilitated a cost-effective approach to the design and structural evaluation of the new high level waste storage tanks. These documents do not connote any legal requirements for either the design or analysis of the tanks to either on-site or off-site contractors. They include overall design criteria, basis for design code selection, and preferred methods of analysis. It was determined to prepare a Hanford Plant Standard (HPS) - Standard Design Criteria (SDC) Document which is designated "Design Loads for Underground High Level Waste Tanks and Associated Underground Process Piping" for this project. The system of Hanford Plant Standards contains the design criteria by which all vendors and contractors are legally required to comply with. This HPS-SDC is designated as 4.3 and includes the minimum design loads, load combinations, and considerations for design and analysis of Project W236A tanks at Hanford. It includes a glossary of terms, site specific soil properties, references, site specific natural phenomena loads, and addresses both underground tanks and piping. This document will be referenced in all Project Design Letters of Instruction and Specifications issued to vendors and contractors alike.

Summary:

Seldom do projects develop guidance documents as described above. This task gave Hanford the opportunity to plan and prepare for the structural analysis of the tanks before actually embarking on the analyses of record. This project also has another advantage in that the conceptual design through detail design was the responsibility of the Site contractor - Kaiser Engineer Hanford. These staff worked in a teaming environment with Westinghouse Hanford Company staff to not only develop the analysis plan, but also prepare the desktop procedures and ultimately perform the analysis of record. This strategy forces consensus, develops depth of expertise, enhances teamwork, establishes a Site memory of design/analysis activities and ensures compliance design requirements.

This activity and these documents will also provide a basis for design of all future tanks and a benchmark for the evaluation of existing tanks.

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