U.S. Department of Energy
Office of River Protection
P.O. Box 450
Richland, Washington 99352

04-WED-040

AUG 0 3 2004

The Honorable John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, N.W., Suite 700
Washington, D.C. 20004-2901

Dear Mr. Chairman:

WASTE TREATMENT AND IMMOBILIZATION PLANT (WTP) LOW ACTIVITY WASTE (LAW) STRUCTURAL REPORT

References: 1. DNFSB letter from J. T. Conway to J. H. Roberson, HQ, dated November 14, 2002.

2. ORP letter from R. J. Schepens to J. T. Conway, DNFSB, "Waste Treatment and Immobilization Plant (WTP) Summary Structural Report (SSR)," 04-WED-018, dated July 9, 2004.

By Reference 1, you asked the U.S. Department of Energy, Office of River Protection (ORP) to develop a "load path report" for the three major WTP process facilities. In Reference 2 we provided you with our outline and schedule for completion of the high level waste (HLW) summary structural report (SSR), the pretreatment (PT) SSR, and an abbreviated structural report for low activity waste (LAW) developed by the ORP peer review team (PRT).

We are pleased to attach for your use, three copies of Revision 0 of the LAW structural report. The basis for this report is an extensive review and evaluation of Bechtel National, Inc. (BNI) drawings and calculations by the ORP PRT together with draft BNI load path evaluations of the LAW structure. From these materials, the PRT was able to develop an understanding of the structural behavior of LAW when subjected to seismic loads. The PRT has found, in general, that the structure behaves predictably and that the design has been competently prepared, with one significant exception, in accordance with criteria and applicable codes. The one exception, which is discussed in the report, is that loads in seismic collectors were not amplified by the omega factor as prescribed by the Uniform Building Code, which is the governing code for performance category 2 structures. BNI is responding quickly to this issue and has initiated design effort this week to add additional collector steel where required and to evaluate alternative load paths for portions of the slab at Elevation 3 ft. that have already been constructed.

The report does list other open issues regarding LAW that will be tracked to closure by the PRT. However, it is believed that sufficient information is available to provide this report to you at this time which should fulfill the need for a LAW SSR.

AUG 0 3 2004

If you have any questions, please contact me, or your staff may call John S. Treadwell, WTP Engineering Division, (509) 373-6355.

Sincerely,

Roy J. Schepens
Manager

WED:JST

Attachment (3 copies)

cc w/attach:
M. B. Whitaker, DR-1
I. R. Triay, EM-3

Hanford Tank Waste
Treatment and Immobilization Plant

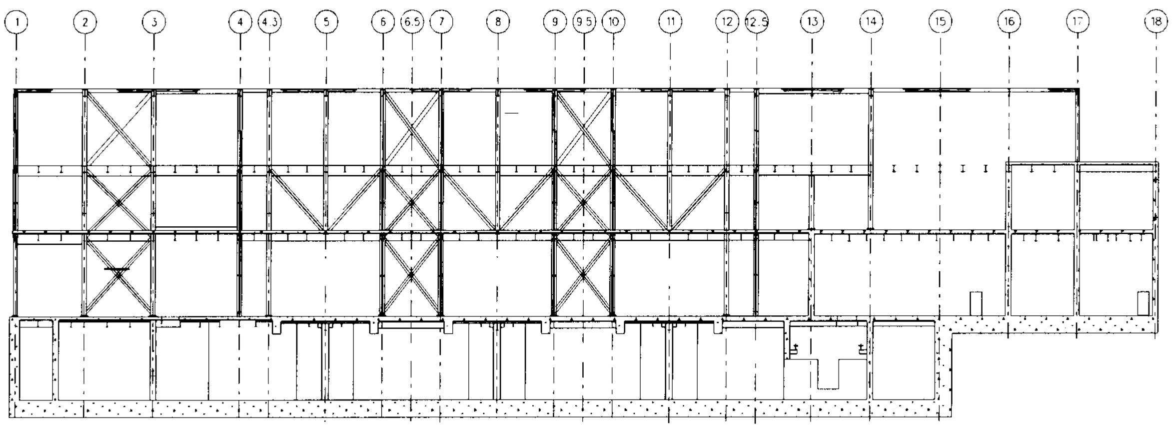
ORP Structural Peer Review Report

LAW Vitrification Building

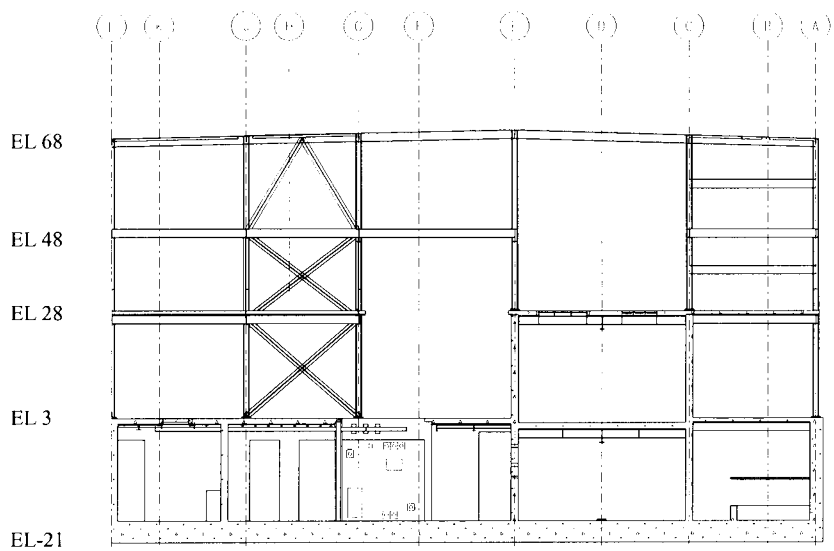
JULY 2004

Revision 0

ORP STRUCTURAL SUMMARY PEER REVIEW REPORT
LAW VITRIFICATION BUILDING
JULY 2004



Column Line G Looking North



Column Line 10 Looking West

U.S. Department of Energy
Office of River Protection
Richland, Washington 99352

OFFICE OF RIVER PROTECTION

WTP LOW ACTIVITY WASTE (LAW) FACILITY

Independent Structural Design Peer Review

Prepared by:

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Approved by Email, 8/26/04
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Approved by Email, 8/26/04
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July 2004

U.S DEPARTMENT OF ENERGY
OFFICE OF RIVER PROTECTION
RICHLAND, WASHINGTON 99352

Disclaimer

Executive Summary

Introduction

The Department of Energy Office of River Protection (ORP) is managing the development and construction of a Waste Treatment and Immobilization Plant (WTP) located at the Hanford Site. Because of the importance of the project and the complex geometry of the building structures, ORP has implemented independent structural design peer reviews of the main WTP process buildings. This peer review report addresses the low activity waste (LAW) facility which will vitrify the low activity fraction of the Hanford tank wastes.

Current LAW Design/Construction Status

Approximately 951,000 design hours were estimated for completion of the LAW design which is currently 74% complete. Engineering is generally on schedule, with Elevation 28ft. and Elevation 48ft. steel drawings issued and releases made for vendor steel fabrication. Steel design continues on Elevation 68ft. steel. Concrete design is currently focused on the slab at Elevation 48ft. which is the top of LAW concrete structures.

The current forecast for LAW total estimated cost is $579M. Construction through May is shown on the cover of this report and is approximately 29% complete. Concrete construction is 43% complete while structural steel is at 3%

Observations and Conclusions

The PRT has reviewed drawings and selected calculations from January to June 2004. The PRT has found, in general, that the design has been competently prepared in accordance with the criteria and applicable codes. The one significant exception is that seismic collectors were not amplified by the omega factor as prescribed by the UBC. BNI has been asked to verify the adequacy of alternate load paths below Elevation +3 where concrete has been cast. The PRT has requested an opportunity to review the redesign at Elevation +28 prior to field placement of reinforcing steel at that level.

Open Issues

The PRT has summarized the PRT's opinion of the LAW structural design in Section 10 of this report including a listing of current open issues needing resolution. Most of these issues are routine review items which the PRT believes can be addressed easily with some changes in details or calculations.

Table of Contents

1 Introduction

The charter for the ORP PRT is to broadly review the Waste Treatment Plant (WTP) design and construction processes to determine if code-compliant design and construction is evident. Reviews have been conducted to evaluate the suitability of the Bechtel National, Inc. (BNI) structural design process for the WTP, reviews have addressed unique features in the WTP design, such as wall and floor offsets, discontinuous walls and floors with respect to load transfer, design modeling, and construction approaches. Facility specific reviews have been conducted on all three major process facilities and will continue until the major design efforts are completed by BNI.

1.1 Purpose

The purpose of this Peer Review Team (PRT) investigation is to provide an oversight that (1) the structural analysis and design of LAW is being conducted in accordance with accepted standards and procedures; and (2) that the "closely coupled" design/construction schedule is proceeding with minimal risks that errors or omissions will result in costly and time consuming repairs and retrofit.

1.2 Scope

The scope of this review included design results for the portions of the LAW building that are presently released for construction and on the design process including preliminary results for the design not yet released for construction. From this assessment, the team evaluates the design-construction interfaces and the suitability of in-place construction and through this report, advises the Manager, ORP on the degree of risk associated with the current design approach.

The PRT review focused on the following:

- Uniform Building Code Requirements,
- Structural Criteria,
- Dead and Live Load Calculations,
- Seismic Loading,
- Design Margins,
- Continuity of the Structural Load Path,
- Critical Structural Members: Loads, Reactions, Sizing, Connections, etc.,
- Unique features in the design, such as wall and floor offsets, discontinuous walls and floors with respect to load transfer,
- Construction to-date,
- Adequacy of in-place construction.

It should be noted that the Independent Structural Peer Review scope did not include the development of the seismic ground motion, the geotechnical characterization of the site, nor functional operation or process.

1.3 Project Overview

The Department of Energy Office of River Protection (ORP) is managing the development and construction of a Waste Treatment and Immobilization Plant (WTP) located at the Hanford Site. Because of the importance of the project and the complex geometry of the building structures, ORP has implemented an independent structural design peer review of the three main WTP process buildings. This peer review is being completed in phases for each building as the design matures.

The Waste Treatment Plant project is a "close-coupled" project. This means that the design is completed in phases and the construction is initiated as each design phase is complete. The LAW building is presently under construction using the close-coupled process and not all phases of the design have been completed. Therefore, the Peer Review Team could only review the design and analysis available to date. The Peer Review Team has reviewed and commented on the assumptions that the BNI design team has implemented to assure that those portions of the design already released for construction have sufficient margin to allow for reasonable design changes in the those portions of the structure that are still in the design phase.

2 PRT Objective

The objective of the PRT was to broadly review the BNI LAW design and construction processes to determine if code-compliant design and construction is evident. This report provides the Manager, ORP an independent evaluation of the suitability of the Bechtel National, Inc. (BNI) structural design process for the WTP and the suitability of the LAW building structural design. The approach used by the PRT included validation of the design criteria, review of selected analysis and design results, review of the LAW seismic load path to insure appropriate design and detailing, and review of in-place construction, construction drawings and details. Through this report, the PRT documents either directly or through references:

- LAW Structural Design Criteria
- Seismic Load Path
- Structural Analysis
- Current Design Results
- Structural Margins in Analysis and Design
- Summary and Conclusions on Adequacy of Design
- Open Issues Requiring Resolution
- Closed PRT Issues

3 General Layout and Function

3.1 Facility Overview

Figure 3-1 illustrates the layout and location of buildings on the WTP site, including the LAW facility, which is immediately East of HLW, other main structures, and transportation rights-of-way. The relationships of the LAW facility features to the major process equipment are summarized below.

3.2 Process Summary

The LAW facility receives treated Envelopes A, B, and C feed from the Pretreatment facility (PT) and processes the feed into vitrified, immobilized low-activity waste (ILAW) meeting US Department of Energy (DOE) requirements for disposal. The three envelopes A, B, and C are constituted as follows:

- Envelope A - This constitutes the largest volume of the waste to be treated and has a nominal sodium concentration of 8 M.
- Envelope B - This is a small volume feed similar to Envelope A, except that it contains higher concentrations of compounds that limit waste loading in the glass (such as sulfates) and has a nominal sodium concentration of 3 M.
- Envelope C - This also consists of waste with constituents that limit waste loading, such as sulfates, but has a nominal sodium concentration of 5 M.

The pretreatment process, which occurs in the PT facility, removes entrained solids and cesium (Cs) from all feed streams, and precipitated strontium/transuranics (Sr/TRU) solids from some of the streams. The entrained solids will be incorporated into the HLW melter feed stream. The precipitated Sr/TRU solids and Cs removed from the LAW feed will be combined with the HLW feed stream for immobilization in the HLW vitrification process. The pretreated LAW feed will be concentrated through evaporation and transferred to the LAW vitrification facility, where it will be blended with glass-forming materials and sucrose, and vitrified in the LAW melters. The LAW melter systems immobilize pretreated Envelopes A, B, and C wastes to meet the LAW vitrification facility waste acceptance requirements when blended with the appropriate glass formers. Two installed melter systems will be employed to immobilize low-activity waste. Provision has been made for installation of a third melter at a later date. Each melter has a nameplate capacity of 15 metric tons of glass per day.

3.3 Building Description Summary

The LAW building is a multi-story reinforced concrete and structural steel building extending from a basement at 21 ft below grade to a roof at 68 ft above grade. The main building extends 331 ft in the E-W direction and 162 ft in the N-S direction. It includes the gaseous effluent stack structure starting at the roof level and terminating 200 ft above grade. The five floor plans and four elevation figures showing space and equipment locations of most interest are included as Figures 3-2 through 3-14. The subsurface reinforced concrete portion of the structure is rectangular in plan. At grade level, the LAW has more complex geometry and includes adjacent structures also constructed of reinforced concrete and structural steel. These structures include drive-through truck bays to the east and west, chemical storage pads and rails for melter import and exports to the south, and the LAW facility annex building, which contains the control room, to the north. The main process building is a four-story structure with a basement. The building's foundation, or basemat, is a reinforced concrete slab nominally 5 ft thick, The basemat has an elevator well in the northeast corner, and embedments and sumps throughout, none of which substantially affect the reinforcing steel design or structural loadings (see section 2.4).

The perimeter basement walls are constructed of cast-in-place reinforced concrete, and the main superstructure will be a structural steel frame. The below grade walls will have standardized penetrations for piping, electrical, heating, ventilation, and air-conditioning (HVAC), and control and instrumentation (C&I) conduits. At grade level, the foundations for the adjacent structures are not attached to the main process building foundation. The exterior wall system for the entire structure will generally be insulated metal sandwich panels. The major roofing system will be metal standing-seam roof over insulation fastened to a metal roof deck. The minor roof systems will be either single ply or modified bituminous roof assemblies. The primary interior functions in the LAW vitrification building consist of provisions for three locally shielded melters and their adjacent supporting process cells, only two are currently being installed. The locally shielded melters are in a melter galleries at the 3 ft level, and are designed to provide radiological shielding and chemical protection. There are also two pour caves under each of the melters, each equipped to provide lifting and transport services for the product containers. The concrete walls surrounding the process cells will have a nominal thickness of 20 in., which provides shielding as well as structural support. Other special features and functions in the facility include lead glass windows, remote camera systems, and closed circuit television (CCTV) for operator viewing of equipment and operations. The interior walls and floors of the pour caves are lined with stainless steel cladding to control contamination and ease decontamination during decommissioning. Some process cell floors are sloped to a sump to allow spills and washdown solutions to be collected and removed.

Structural design is relatively straight forward except for the following locations:

- The principle component of LAW is the melter and since it has to be replaced on a 3 to 6 year schedule it is located at ground level with rail access. There will be two active melters with reserve space for a third one. This requires a major floor at ground level +3 feet.
- Three 30ft wide Pour Cave structures extend 21 feet below grade from the mid point of the building to the south. Below grade, the interior and exterior walls provide resistance to the story shear and carry the load to the foundation. These exterior walls are connected monolithically to the slab at Elevation 3 ft and the foundation. However, the

E-W location of the pour caves cause the walls above and below Elevation +3 ft to be offset

- The process cell at Elevation +3 ft contains tanks that feed the melters and handle the offgas treatment. The process cell is subdivided into four adjacent cells extending approximately 160 ft in the E-W direction, each surrounded by 20 inch thick concrete walls which extend to the Elevation +28 ft floor. These concrete walls, running from Column Lines E&4 to C&14 in Figure 3-3, resist the majority of the north-south lateral seismic loads above the +3 foot floor level.
- In addition to the slabs at Elevations -21 ft and Elevation 3 ft there are concrete floor slab diaphragms supported on steel framing at nominally 28 and 48 feet above grade.
- The finishing line walls, running form Column Lines J.4&13 to G&18, and the process cell walls resist East-West lateral seismic loads above the +3 foot level.
- Above the +28 foot floor level, the lateral seismic loads in both directions are resisted by structural steel braced frame. Additional lateral resistance to North-South loads is provided by vertical Vierendeel trusses which are located North of the process cells.

To show the contribution of the weight of various components to the total weight, Table 1 developed in October, 2002, illustrates the attributes and shows distribution of the weight along the height of the building at that time. [Minor changes have occurred during design development but the conclusions remain the same.] About 71 % of the weight is from the dead weight of the concrete members. The explicitly modeled equipment weight (components >5 kips) amounts to about 7 % of the total weight with the uniform dead weight (misc. equipment, mechanical and electrical) amounts to about 17% of the total weight.. As shown in this table, over 74 % of the total weight is at or below grade with heaviest floor (47 %) at -21 ft followed by the +3 floor (27 %).

LAW Structural Load Distribution

Elevation (ft)	-21		+3		+28		+48		+68		stack		% of Total
Load Description	kips	%/floor	kips	%/floor	kips	%/floor	kips	%/floor	kips	%/floor	kips	%/floor	
Concrete Structure	53088	91	21595	66	7063	48	5396	44	0	0	0	0	71
Steel Structure	415	1	776	2	1993	14	2176	18	1070	23	84	52	5
Dead Load	3034	5	5113	16	5250	36	4254	34	3345	72	78	48	17
Equipment	1545	3	5485	17	275	2	556	4	225	5	0	0	7
Total	58081		32970		14581		12381		4640		162		122815
% of Total	47.3		26.8		11.9		10.1		3.8		0.1		100.0

Table 3.1 - LAW Component Loads

Figure 3-1 WTP Site General Arrangement Plan

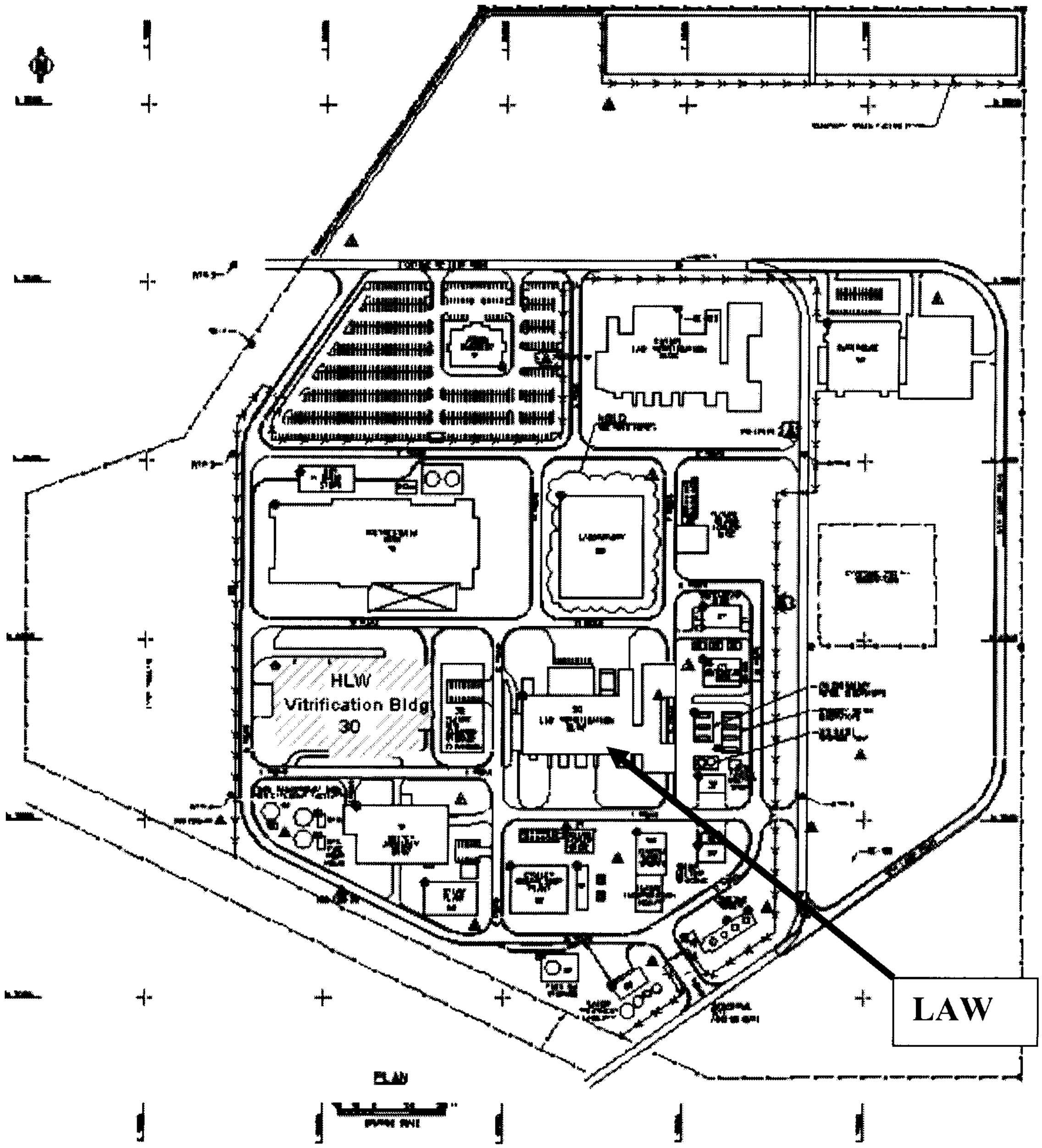


Figure 3-2 General Layout Elevation -21 to +3

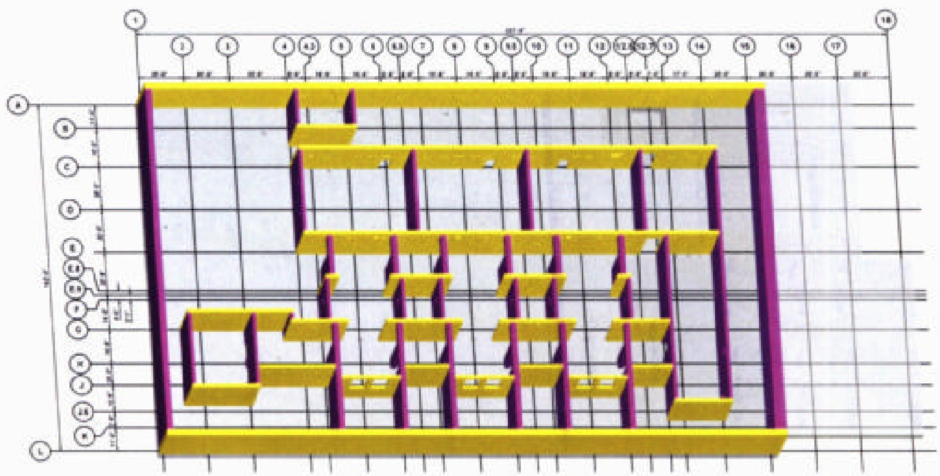


Figure 3-3 General Layout Elevation 3+ to 28'

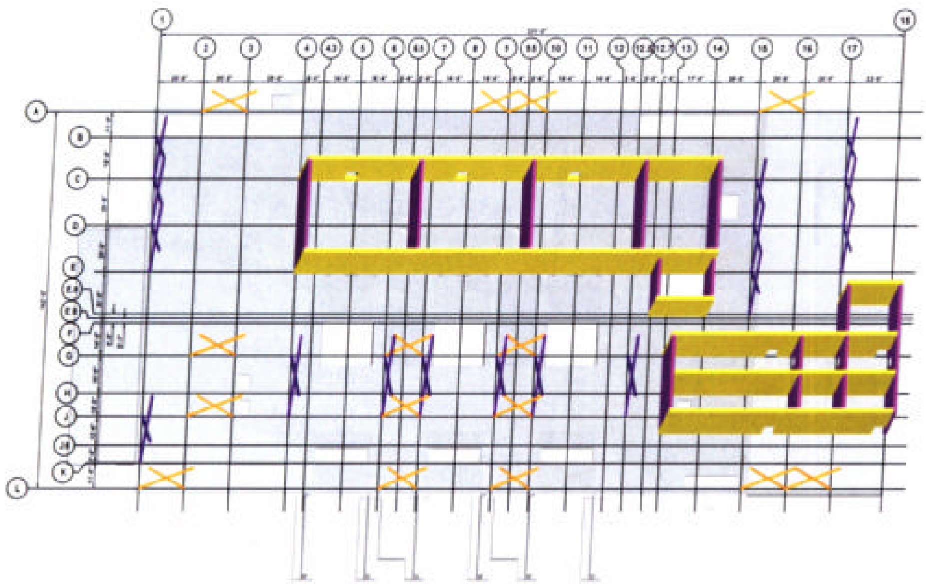


Figure 3-4 General Layout Elevation 28' to 48'

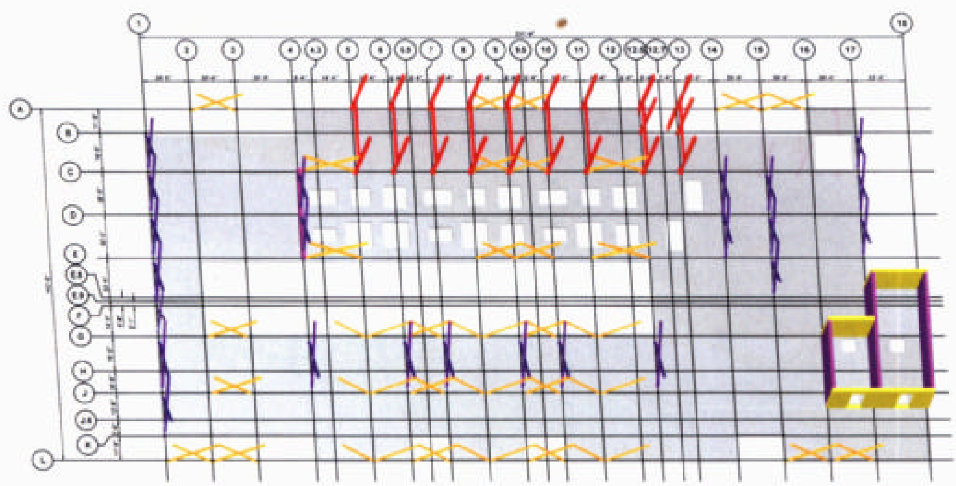


Figure 3-5 General Layout Elevation 48' to 68'

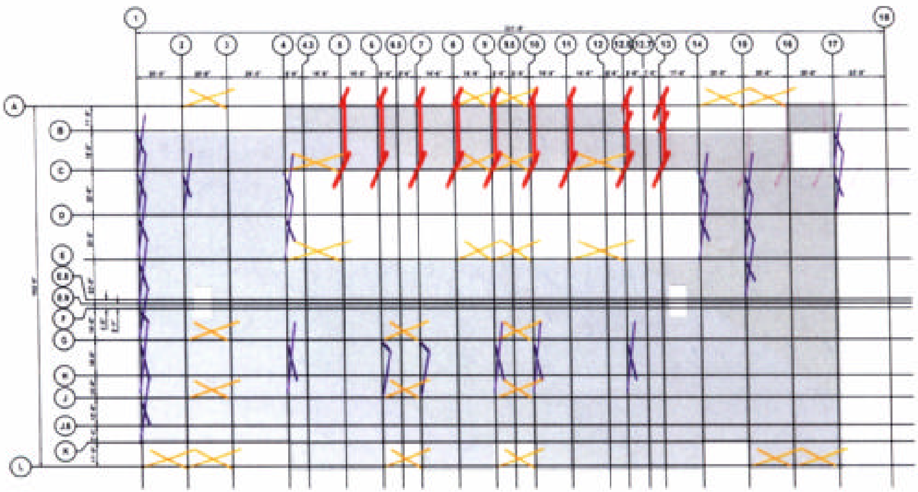
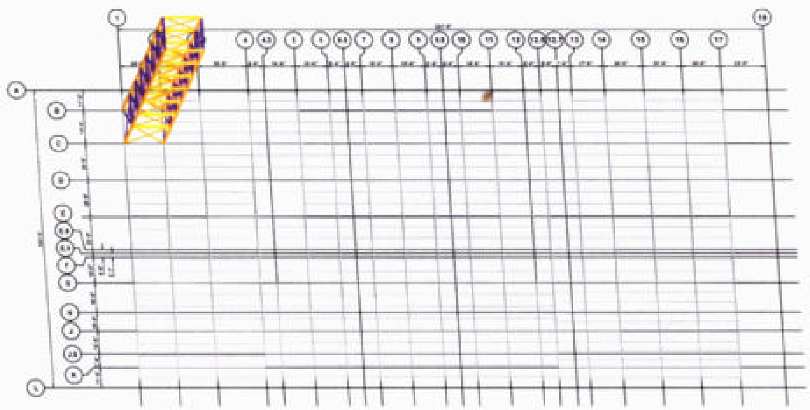


Figure 3-6 General Layout Elevation 68'



4 Design and Construction Status

The WTP design and construction activities are closely coupled following a design/build approach. In December 2000, the contract to design, construct and commission the WTP was awarded to BNI following the unsuccessful privatization contract which was terminated due to high costs. Construction was started in October 2001, on limited (non-safety related) facilities and in February 2002, the preliminary safety analysis report for LAW was submitted for DOE review. After DOE approval in August 2002, LAW construction was allowed to proceed.

4.1 Design Status

Approximately 951,000 engineering hours were estimated for completion of the LAW design which is currently 74% complete. The current forecast for LAW total estimated cost is $579M. Engineering is generally on schedule, with Elevation 28 ft and Elevation 48 ft steel drawings issued and releases made for vendor steel fabrication. Steel design continues for the Elevation 68 ft steel. Concrete design is currently focused on the slab at Elevation 48 ft, which is the top of LAW concrete structures. Engineering accomplishments for May 2004 included:

- Issued for construction Elevation 48 ft framing and associated columns and bracing.
- Issued cable tray drawings for Elevation 3ft.
- Issued HVAC V&IDs and orthographic drawings for Elevation 48 ft.

4.2 Construction Status

A photograph of the LAW construction as of the end of May is shown on the cover of this report. Concrete construction is 43% complete while structural steel is at 3% and total construction is 29% complete. Construction accomplishments for May 2004 included:

- Structural steel delivered for elevation 3 ft. to 28ft. and steel erection commenced.
- Procurement was started for structural steel from Elevation 28 ft to Elevation48 ft.
- Commenced cable tray installation at Elevation -21 ft.
- Twenty five wall segment placements were completed between Elevation 3 ft to Elevation 28 ft.

5 Structural Design Criteria

The LAW is designed in accordance with two primary requirement documents, *Seismic Analysis and Design Approach*, (24590-WTP-RPT-ST-01-002, and, *Structural Design Criteria*, 24590-WTP-DC-ST-01-001) plus specific requirements to the LAW facility. The specific requirements, which are part of the projects Authorization Basis, are summarized Section 5.2.

5.1 Categorization of Structures, Systems and Components

The LAW structure is designated as Seismic Category III (SC-III) for earthquakes and performance category 2 (PC-2) for other natural phenomena hazards (NPH). The LAW structure is also classified important to safety (ITS). Seismic analysis is described in detail in "Seismic Analysis and Design Approach," (24590-WTP-RPT-ST-01-002)

5.2 Requirements, Codes, and Standards

Codes and standards applied to the civil/structural design and construction of the Seismic Category III LAW facility are summarized in Table 5.1. The PRT observes that the codes and standards utilized in the LAW structural design are consistent with the design of other facilities in the DOE complex. It is also observed that the revisions of specific DOE and NCS codes and standards are associated with the date of the authorization basis, and in some cases newer revisions exist. The PRT will cite requirements in later revisions as applicable only if structural safety is compromised by using the older requirements.

Table 5.1 LAW Structural Design Codes and Standards

Application	Code or Standard
Minimum Live Loads	ASCE 7-98, Minimum Design Loads for Building and Other Structures
Design Criteria for Natural Phenomena Hazards	DOE-STD-1020 Change Notice #1 (1996), Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities
Wind and Tornado Loads	DOE Newsletter, Interim Advisory on Straight Winds and Tornadoes, January 22, 1998
Wind Load Design Methodology	ASCE 7-98, Minimum Design Loads for Building and Other Structures
Seismic Analysis and Design	24590-WTP-RPT-ST-01-002, Rev 2 *Seismic Analysis and Design Approach*
Seismic Analysis	UBC 1997, Uniform Building Code - Chapter 16
Snow Load Design Methodology	ASCE 7-98, Minimum Design Loads for Building and Other Structures
Load Combinations	24590-WTP-DC-ST-01-001, Rev 3, *Structural Design Criteria*
Design of Reinforced Concrete Structures – Strength Design Method	ACI 318-99, Building Code Requirements for Structural Concrete
Seismic Detailing of Concrete for Moderate Seismic Risk Regions	ACI 318-99, Building Code Requirements for Structural Concrete – Chapter 21
Design of Structural Steel – Allowable Stress Design Method	AISC M016, Manual for Steel Construction, Ninth Edition
Seismic Detailing of Structural Steel	UBC 1997, Uniform Building Code – Section 2214
Anchorage Design for "Important To Safety" (ITS) Applications	ACI 349, Code Requirements for Nuclear Safety Related Concrete Structures, Appendix B, "Fastenings to Concrete"
Design of Post-Installed Concrete Anchors for Non-Important to Safety Applications	International Council of Building Officials Evaluation Services (ICBO-ES) Reports
Design of Steel Deck	Steel Deck Institute Design Manual for Composite Decks, Form Decks and Roof Decks No. 30 Institute, April 2001

5.3 Design Loads

Design loadings are briefly summarized in this section. It is the PRT's opinion that the design loads used in the LAW design generally contain an adequate level of conservatism. The PRT acknowledges that major equipment loads are based on conservative assumptions that must be validated as vendor information becomes available.

5.3.1 Dead Load, D

A dead load (D) is a structural load considered to act permanently. Actual weights and locations are used for equipment weighing more than 5,000 lb.

The following dead loads, which are input to the analysis model, were observed in Calculation 24590-LAW-S0C-S15T-00002 Rev 1:.

- Self weight of the structure
- 50 psf commodity load on the basemat and roof (Elevation +68)
- 80 psf commodity load on the elevated slabs at Elevation +3, +28 and +48
- 20 psf partition load Elevation -21, +3, +28 and +48
- Major equipment weights representing turntables, melters, full containers, container elevators, shield doors, cranes, bogies, filters, fans, storage tanks, etcetera

These dead loads were also observed:

- The slab design at Elevation +3 ft, Calculation 24590-LAW-DBC-S13T-00015 Rev A. Note that the commodity load is not applied to the slab design.
- The steel floor beams at Elevation +3 ft, Calculation 24590-LAW-SSC-S15T-00009 Rev 0A. Note that the commodity load is applied to the steel beams.

Where final weights have not yet been determined, estimates are used and the design must be confirmed when final weights are obtained.

5.3.2 Live Load, L

A roof live load of 20 psf is included for the LAW facility design.

Uniform floor live loads are generally 100 psf in the LAW. The uniform floor live load in the crane maintenance area is 250 psf.

Additional concentrated floor loads on the +3 foot floor of 8 kips on 12 inch and 20inch slabs; or 20 kips on 18 inch slabs; are also included in the LAW floor slab and floor beam design.

Uniform roof and floor live loads, which are input to the analysis model, are observed in Calculation 24590-LAW-S0C-S15T-00002 Rev 1.

Both uniform and concentrated floor live loads are observed in Calculations 24590-LAW-DBC-S13T-00015 Rev A and 24590-LAW-SSC-S15T-00009 Rev 0A for the Elevation +3 ft floor.

Live loads reductions for normal operating loads are not used in the design of LAW floors, columns nor their foundations.

5.3.3 Snow Load, SN

Roof snow load including snow drift is based on a ground snow load of 15 psf with an importance factor I=1.0.

5.3.4 Ashfall Load, A

The ashfall load for the LAW is 5 psf.

5.3.5 Wind Load, W

Wind loads are calculated in accordance with ASCE 7 with a basic wind speed of 91 mph 3-second gust at 33 ft above ground with an Importance Factor of one, I=1.0, and Exposure C. Wind loads are observed in Calculation 24590-LAW-S0C-S15T-00005 Rev 1.

Per DOE-STD-1020, there are no wind borne missiles for PC-2 structures. Tornado loadings and tornado missiles are not applicable to the PC-2 LAW building.

The LAW wind and tornado load criteria is equivalent to the wind and tornado load criteria in DOE-STD-1020-2002.

5.3.6 Lateral Earth Pressure, H

The below grade walls resist lateral earth pressures from at-rest soil loads, surcharge loading adjacent to the facility, and loads induced as a result of a seismic event. The lateral seismic soil pressure acting on below grade walls is equivalent to the ASCE 4 elastic solution.

Surcharge loads observed in the LAW calculation 24590-LAW-DBC-S13T-00001 Rev 1 include

- A 100 kip construction load due to a soil compactor, which is treated as a 400 psf surcharge load.
- Glass melter loads treated as a 1180 psf surcharge.
- Annex building weight treated as an 1100 psf surcharge.
- The surface foundation east of Column Line 15 is treated as a 1850 psf surcharge.

In Calculation 24590-LAW-DBC-S13T-00001 Rev 1, active lateral soil pressures during construction are calculated with an active soil pressure coefficient Ka=0.21. At rest lateral soil pressures are calculated with an at rest soil coefficient Ko=0.338. Lateral pressure due to surcharges are calculated with a lateral soil pressure coefficient K=0.4.

5.3.7 Thermal Loads

Thermal loads are considered in the pour cave and buffer storage areas.

Computational fluid dynamic calculations are performed to size cooling and insulation so that average concrete operating temperatures in the pour caves do not exceed 150°F. Average basemat temperatures of approximately 150°F and peak basemat nodal temperatures of 170°F were observed in Calculation 24590-LAW-DBC-S13T-00005 Rev 0. A 70°F base temperature was used. The basemat was also evaluated for a 30°F thermal gradient in Calculation 24590-LAW-DBC-S13T-00009 Rev 2.

Thermal loads in the buffer storage area were not reviewed.

Thermal accident loading is observed in Calculation 24590-LAW-DBC-S13T-00014, which removes basemat elements to account for postulated thermal damage.

5.3.8 Creep and Shrinkage Forces

The LAW building reinforced concrete structural system is not sensitive to creep and shrinkage. Creep and shrinkage are addressed by meeting the ACI minimum reinforcing requirements.

5.3.9 Fluid Load, F

Loads due to weight of fluids are included as dead loads in the load combinations for design of the LAW facility structure. For lateral seismic loads, Calculation 24590-LAW-SSC-S15T-00023 Rev A conservatively assumes 100% of the process cell fluid mass participates in the impulsive mode.

5.3.10 Operating Pipe Reactions, R

Operating pipe reactions are evaluated for specific locations where piping penetrates walls as observed in Calculations 24590-LAW-DBC-S13T-00011 Rev 2B and 24590-LAW-DBC-S13T-00018.

5.3.11 Seismic Load

The LAW Seismic loads are based on UBC-97 with the following parameters:

- Importance factor, I=1.25
- Seismic Zone 2B
- Soil Profile Sc
- Ca = 0.24
- Cv = 0.32
- R = 4.5 (concrete shear wall value governs)
- Ω = 2.8 for concrete shear wall systems
- Ω = 2.2 for ordinary steel braced frames

These seismic parameters are observed in Calculations 24590-LAW-S0C-S15T-00001 Rev 0, GTStrudl Finite Element Analysis Model and 24590-LAW-S0C-S15T-00013 Rev A, GTStrudl FEA Model Update 3.

DOE-STD-1020-2002 references IBC-2000, with an importance factor, I, of 1.5 for PC-2 buildings. The IBC-2000 input spectra, with I=1.5, is compared to the UBC-97 seismic spectra used in the LAW design in Figure 5-1. These two spectra are essentially equal in the LAW fundamental period (about 0.4 sec). Thus, the seismic input used to design the LAW is consistent with DOE-STD-1020-2002.

5.3.12 Flood Load

The LAW structure is not susceptible to flooding.

5.3.13 Dropped Load Design

Load drops that could affect the facility are identified and evaluated.

5.3.14 Differential Settlement

Differential settlement loads are calculated as Winkler springs under the foundation.

5.4 Design Requirements

The following design requirements are specific to the LAW structure. In general the PRT observes that the design requirements are consistent with the state of practice in the DOE complex. One positive exception is the recently completed criteria for post-installed anchor bolts which, in the PRT's opinion, is a proactive implementation of recent improvements to anchorage design.

5.4.1 Reinforced Concrete Design

Reinforced concrete elements are designed in accordance with ACI 318-99. Seismic proportioning and detailing is in accordance with the provisions of ACI 318 Chapter 21 pertaining to structures in Moderate seismic risk regions. The operating and accident temperature of concrete is limited by ACI 349-01 Appendix A.

5.4.2 Structural Steel Design

Structural steel elements are designed in accordance with *Allowable Stress Design Method Utilizing the Manual of Steel Construction*, AISC ASD 9th Edition. Seismic proportioning and detailing is in accordance with UBC 97 Section 2214, Seismic Provisions for Structural Steel Buildings in Seismic Zones 1 and 2.

5.4.3 Load Factors and Load Combinations

Load factors and load combinations for the design of the LAW facility are in accordance with the general Structural Design Criteria (24590-WTP-DC-ST-001).

The load combinations for reinforced concrete are based on ACI 318 with the following enhancements:

- Either roof live load plus ash load; or snow loads are considered
- Load combinations with 0.9D per ACI 318 Section 9.2.4 are explicitly stated
- Fluid, F, load combinations per ACI 318 Section 9.2.5 are explicitly stated
- Operating pipe reaction loads are added to the thermal load combinations
- Additionally, UBC 97 Section 1612.2.1 Equations 12-5 (D+L+E) and 12-6 (D+E) are included, along with a 1.1 increase for seismic loads. Equation 12-5 is enhanced by adding fluid, lateral soil, thermal and operating pipe reaction loads.

The load combinations for structural steel are based on alternate basic load combinations of UBC-97 Section 1612.3.2, with the following enhancement:

- Roof live load plus ash load; or Roof live load plus snow load are considered.

These loading combinations are implemented in the GT Strudl model in Calculation 24590-LAW-S0C-S15T-00007 Rev 0, *Loading Combinations*. The loading combinations are observed throughout the concrete and steel design calculations.

The special load combinations of UBC-97 Section 1612.4, which increase the seismic load in collector elements and braced frame connections, were is not explicitly listed in the Structural Design Criteria. It is the PRT opinion that this oversight was a contribution factor in the omission of the omega factor, Ω, from the Elevation +3 ft collector element design (See Issue LAW-11 in Chapter 12 of this report). The PRT recommends that BNI revise their design criteria to include the special load combinations of UBC-97 Section 1612.4.

5.4.4 Stability Requirements for Building Structures

Minimum factors of safety of 1.5 for sliding and overturning are required.

5.4.5 Deflection Limits

The deflection of reinforced concrete members is limited by adhering to the depth to span ratios in ACI 318 Section 9.5. The deflection of steel beams is limited by adhering to the following requirements:

- Floor beam depth > Fy/800
- Purlin depth > Fy/1000
- Live load deflection < Span/360
- Dead plus live load deflection < Span/240
- Maximum vertical deflection of a crane beam = Span/1000
- Maximum lateral deflection of a crane beam = Span/400

5.4.6 Anchorage

Anchorages for Important To Safety (ITS) applications are: :

- Cast-in-place embeds are designed to ACI 349-01 Appendix B
- Post installed anchors are currently limited to Drillco Maxibolts, per 24590-WTP-3PS-FA02-T00005 Rev 0, *Design of Post Installed Concrete Anchors for Important to Safety (ITS) Applications*. The Maxibolts are designed to ACI 349 Appendix B.

ITS anchorage use the improved Concrete Capacity Design (CCD) method with capacities that are generally based on assumed cracks. Previous codes utilized a less conserved cone method for anchorage design and neglected the detrimental influence of cracks on anchorage capacity.

Post installed anchorages for Non-Important To Safety applications are designed in accordance with their ICBO ES report per 24590-WTP-3PS-FA02-T00003 Rev 0, *Design of Post Installed Concrete Anchors for Non-Important to Safety (Non-ITS) Applications*.

The Structural Design Criteria (24590-WTP-DC-ST-001) provides different criteria based on seismic category, I – V, which is not consistent with the recent specifications for ITS applications (May 2004) and Non-ITS applications (Oct 2003). The PRT recommends that the Structural Design Criteria (24590-WTP-DC-ST-001) be updated to remove this inconsistency.

5.4.7 II over I Interaction Requirements

There are PC-1 buildings adjacent to the LAW building which could have an adverse impact on the LAW building if they failed. Specific design criteria to preclude II over I interactions has not been located by the PRT. The PRT recommends that BNI develop II over I evaluation criteria for structures, systems and components and include this criteria in the Structural Design Criteria (24590-WTP-DC-ST-001).

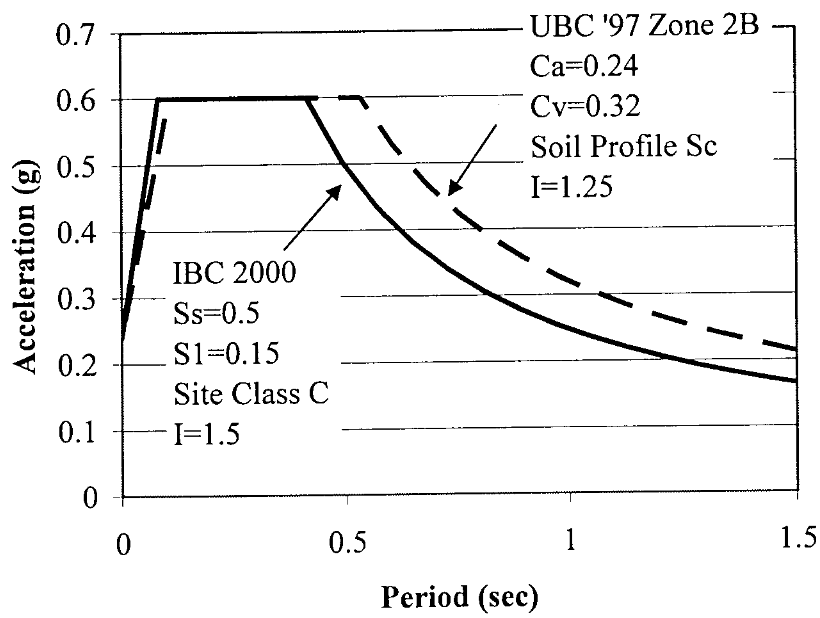


Figure 5-1 Comparison of UBC-97 and IBC-2000 Spectra

6 Seismic Load Path

This chapter describes the lateral load path of the LAW building. It also provides Peer Review Team (PRT) comments relative to its review of the BNI incorporation of the load path into the structural design. The primary source for the load path description is a draft report prepared by BNI early in the design phase that describes the load distribution throughout the structure [Reference 16] along with available construction drawings. The draft report shows the distribution of total lateral loads in the load resisting members at each floor elevation as a percentage of cumulative story shear. The draft report was based on the configuration of the structure prior to October, 2002, and as such is only a reasonable approximation to the load path for the current design.

6.1 Lateral Load Path

The lateral force resisting system of the LAW Building consists of a combination of structural steel concentric braced frames and reinforced concrete shear walls. Above the floor slab at Elevation 28 ft, there are no shear walls to provide lateral force resistance and all the lateral seismic forces are resisted by the steel braced frames. An exception is for north-south forces north of line C where there is a long opening at the Elevation 48 ft slab over the process cell areas. This area was stiffened by using Vierendeel Trusses that span vertically from Elevation 28 ft to Elevation 68 ft. Above Elevation 48 ft the building is entirely a braced frame. A description of the load path and elements of load resistance for each story is presented in the sections below.

6.1.1 Load Path Elevation -21 ft to Elevation 3 ft

Below the floor slab at Elevation 3 ft, lateral forces are resisted by reinforced concrete shear walls that span from the top of the basemat to the slab at Elevation 3 ft. These walls are shown in Chapter 3, Figure 3.2. Since the floor slab at Elevation 3 ft is generally solid, having only a few large openings, the seismic forces are resisted by the concrete walls, generally in proportion to their stiffness, so the stiffer walls carry a majority of the lateral load. The distribution of the lateral load as a percentage of story shear is shown on Figure 6.1 and Figure 6.2. These figures based on the information from the draft load path report [Reference 16]. It should be noted that some of the lateral forces above Elevation 3 ft are transferred into the soil beneath the high foundation at grade east of line 15, where no basement exists

6.1.2 Load Path Elevation 3 ft to Elevation 28 ft

The lateral load path between Elevation 3 ft and Elevation 28 ft consist of reinforced concrete shear walls and braced frames as seen in Chapter 3, Figure 3.3. In the east-west direction the majority of the load is taken by the shear walls, whereas, in the north-south direction the lateral load is more evenly distributed between the shear walls and the braced frames. In this story the lateral forces are resisted by a combination of concrete shear walls and steel braced frames. There are considerably fewer shear walls in this story than in the basement story. In the east-west direction there are two long walls on lines C and E and three shorter walls on lines G, H and J.4, which form the container finishing lines. In the north-south direction there are five walls along the process cells and effluent cell between lines C and E on lines 4, 6.5, 9.5, 12.5 and 14. Seismic forces in this story tend to be resisted by these concrete walls as they are considerably stiffer than the steel braced frames. However, the load transfer is not straight forward due to the large opening in the Elevation 28 ft floor diaphragm between lines E to G and lines 2 to 12.5. This large opening prevents the transfer of significant seismic forces south of line G to the north-south walls north of line E. The result is that in the story between the Elevation 3 ft floor diaphragm and the Elevation 28 ft floor diaphragm, about 88 percent of the east west seismic forces are resisted by the east-west concrete shear walls while only about 49 percent of the north-south seismic forces are resisted by the north-south concrete shear walls. The remainder of the seismic force in this story is resisted by the steel braced frames. This situation complicates load transfer, especially in the Elevation 3 ft and Elevation 28 ft floor diaphragms. The distribution of the lateral load, as a percent of total story shear, in the east-west and north-south directions is show in Figure 6.3 from Reference 16.

6.1.3 Load Path between Elevation 28 ft and Elevation 68 ft and Roof Stack

The only concrete structure extending above Elevation 28 ft are small walls providing shielding around a portion of the container finishing lines in the SE corner of the building. This concrete is isolated from the rest of the building so it does not attract load or distort building seismic reactions. The lateral load carrying system above Elevation 28 ft is shown on in Chapter 3, Figures 3.4 and 3.5. The lateral force resisting system above Elevation 28 ft is steel braced frames. One unusual feature is located over the process cell areas where the slab opening at Elevation 48 ft results in a very flexible diaphragm. At this level, moment resistant steel frames with mid-story beams are provided at lines 5, 6, 7, 8, 9, 10, 11, 12.5 and 13 from A to C. These moment resisting frames, or Vierendeel Trusses, span from the Elevation 28 ft floor to the Elevation 68 ft floor and help stiffen the Elevation 48 ft floor diaphragm in this area to reduce local diaphragm deflections. Above Elevation 68 ft there is a steel stack that extends to Elevation 132 ft. The Elevation 68 ft floor and the stack structure are shown in Chapter 3, Figure 3.6. The lateral load distribution, as a percentage of total story shear, for these elevations are shown on Figures 6.4 and 6.5, which are from Reference 16.

6.2 BNI Design Approach

BNI prepared a load path report for the LAW Building in October 2002. The report titled, "Lateral Load Path in the Low Activity Waste Vitrification Building", document 24590-LAW-RPT-CSA-02-002, Rev. A, [Reference 16], was a Draft for Review, which was never completed nor issued. A copy of this report was provided to the PRT.

This report was based on the Update 2 version of the GT Strudl computer model. It appears that this study was significant in the early design of the LAW Building and led to modifications of the steel bracing layout and member sizes. Other than providing a good understanding of the seismic load path issues, this report has not been used in the detailed design of the lateral force resisting system or to identify the locations of critical load path transfers.

For the detailed design, BNI has relied on the GT Strudl results. For the floor diaphragms, the design team has plotted key structural characteristics, such as in-plane shear and axial loads in color coded contour plots. The designers have used these colored coded plots to guide them where to take section cuts and perform detailed design calculations.

6.3 Peer Review Team's Approach to Load Path Verification

The PRT has used the October 2002 Draft Load Path Report to guide the review of the design for verification of load path issues. The PRT took the percentage of story shear in each wall or group of steel diagonal braces from the Draft Load Path Report and multiplied the percentage by the Update 4 story shears. The PRT felt it was important to use the Update 4 seismic story shears since they are about 2/3 of the Update 2 loads. The PRT also recognizes that some steel braced frames were modified after the Update 2 model was developed, so some inaccuracies are to be expected between the "rough" shears in various walls and braces by this approximation and the actual shears BNI has calculated using the Update 4 model. However, several checks between the PRT's "rough" or approximate loads and BNI's calculations showed a variation of less than 10 percent, so the PRT feels that this procedure provides a good understanding of the load path and load transfer requirements for an independent review of the calculations.

6.4 Verification Results

The PRT conducted three reviews of the LAW structure. The first review in January, 2004, provided the team with an overview of the LAW layout and function, modeling and analysis activities, information from BNI's draft load path report cited above, and current status of both concrete and steel construction. The timing of the PRT review for the concrete portion of the structure was critical as the basemat, walls to grade and most of the slab at Elevation 3 ft had been placed. Only a small portion of the floor slab under the process cells remained to be completed. Structural steel construction was not yet started but material procurement was well underway. As a result of this first review and subsequent data exchanges, several questions arose over the load path as well as the concrete and structural steel detailing. A second meeting with the BNI LAW design team was held in March where two key remaining issues were discussed. The first issue involved adequacy of collector element design in reinforced slabs and the second issue involved structural steel gusset connections. Through a series of correspondence and discussions, the structural steel questions were resolved. Adequate information was now available to prepare the structural report with the understanding that the following issues still need to be addressed.

- **Amplification of Collector/Drag Strut Forces.** The LAW Building is a PC-2 building and is designed in accordance with the 1997 Uniform Building Code (UBC) for seismic loads. A reduction of seismic loads is permitted by the UBC with an R value to recognize the ductility inherent in various lateral force resisting systems. For the LAW Building, an R of 4.5 was used for a reinforced concrete shear wall system. Thus, the seismic loads are reduced by a factor of 4.5 recognizing the ability of the system to slightly crack and maintain resistance throughout the earthquake in a ductile manner. UBC Section 1633.2.6 requires the loads in collectors (and drag struts) to be multiplied by the omega (Ω) factor in order for these critical elements to have additional capacity and not be a weak link in the lateral force resisting system. For the LAW Building, the amplification factor Ω is 2.8. BNI has not used the omega factor in their calculations. The PRT was initially told that the omega factor did not apply since the site is in UBC Zone 2B. However, UBC Section 1633.2.6 is a general seismic design requirement and is applicable to all seismic zones. Thus the design to date is deficient in this critical issue affecting the load path. The PRT is committed to ensuring that the design is modified to correct this deficiency

- **Load Path Issues at Elevation 3 ft Slab.** The major load transfer issues at Elevation 3 ft involves transferring seismic loads out of the north-south walls above Elevation 3 ft on lines 4, 6.5, 9.5, 12.5 and 14 from lines C to E to the extensive north-south walls south of line E below Elevation 3 ft. The responses the PRT received from BNI were confusing as the transfer forces at line E were not the full seismic load. During the June 1 to 3 site visit some special calculations were performed to study this issue. There appears to be a considerable gravity load resulting in a north-south compression in the Elevation 3 ft floor slab in the vicinity of line E, which reduces the seismic tension calculated by the project's load combinations.

  Although not verified, the north-south compression load is believed to be a result of the very heavy weights of the melters on the Elevation 3 ft floor slab just south of line E. Since this gravity compression may not be a reliable permanent load considering construction sequence and melter installation, the PRT recommends that these gravity load compressions not be used to reduce seismic collector loads.

  The PRT has had extensive discussions with the project team regarding these load path issues north and south of line E. With the omega amplification factor and ignoring the gravity compression in the Elevation 3 ft floor slab, some of the north south collectors were not adequately sized. The concrete has been cast so it would be difficult and costly to change the design. The PRT believes that once the slab experiences some cracking during an earthquake that alternate load paths are available to accommodate the load. The PRT recommends that BNI prepare calculations to address this issue and document the presence of an adequate alternate load path.

- **Load Path Issues at Elevation 28 ft Slab.** Above Elevation 28 ft, all seismic loads are resisted by the structural steel diagonal braces. Below Elevation 28 ft, there is a mix of concrete shear walls and steel diagonal braces. The primary load path issue at Elevation 28 ft is the transfer of seismic forces from the steel bracing above to the stiffer concrete shear walls below.

  The collector/drag strut calculations for the Elevation 28 ft slab were performed without the amplification factor Ω required by code at that level. The PRT has strongly encouraged BNI to recalculate these collector forces and increase the reinforcing in the slab as needed prior to placement of steel at this level. The PRT understands, based on discussions with the design team, that this will be done. Whereas, the lack of using omega for the Elevation 3 ft floor slab can probably be justified by alternate load paths, this probability does not appear to exist at Elevation 28 ft and an after-the-pour retrofit would be extremely difficult and costly.

- **Utilization of Stress Plots**. The design approach has been to utilize the color coded stress contour plots that plot shear or tension in the concrete slab to guide the designers to locate section cuts and calculate reinforcing steel. The PRT reviewed the calculation for the concrete slab design for the Elevation 28 ft floor slab, (24590-LAW-DBC-S13T-00028). For collector design, the design team identified areas of high slab tension and then preformed section cuts in the GTStrudl model. They combined tension in the concrete plus tension in the steel member between computer model nodes and designed the slab for the total tension demand. The PRT supports this design procedure and finds it acceptable. However, the PRT has the following observations and concerns regarding the adequacy of this procedure.

- The PRT is not certain that the design procedure has adequately captured all the collector demands at the Elevation 28 ft floor slab. As an example, consider the east-west collectors need to transfer seismic forces from the extensive steel bracing and transfer trusses, which act as additional steel bracing, on lines G, J and L from lines 1 to 11 above Elevation 28 ft to the three concrete shear walls on lines G, H, and J.4 east of line 13 below Elevation 28 ft. These three concrete walls resist about 4,500 kips of seismic shear, or about 25% of the seismic story shear. In the calculations, the PRT observed two section cuts in this area. On pages 175 to 178, an 8-foot wide section cut from lines G to G.3 was taken. On pages 179 to 182 another 8-foot wide section cut from line G.3 to G.5 was taken. The calculations concluded that #9 bars at 6 inch centers top and bottom were required and this reinforcing was extended from G to H. South of line H the reinforcing becomes #7 bars at 6 inch on center and neither section cuts nor calculations were found for this reinforcing. Also the calculations reviewed did not include the omega factor. When the omega factor is included it is possible that additional reinforcing will be required. The PRT recommends that the design team review its procedures and perform additional section cuts in areas of moderate tension to ensure that all collector demands are adequately reinforced. The criteria that the design team uses to review the color coded tension plots may have to be supplemented to assure that the omega factor in included.

- The PRT is concerned that the present design procedure of using the color codes concrete tension plots may not envelope high tension forces in the steel framing members. The PRT could not locate any steel tension contour plots or determine how high steel beam tension forces were identified for proper design. The PRT recognizes that large numbers of similar beams were bracketed for common design. BNI should identify how they address this issue to ensure that high tension forces in steel beams are properly addressed in design process, including the use of omega for collector loads. While this issue applies to Elevation 28 ft, it will also apply at higher levels in the building.

6.5 Conclusion

The PRT recognizes that the steel design at the roof at Elevation 68 ft has not yet been completed. The PRT understands that a concrete slab will not be provided at this level and that steel diagonal members in the plane of the floor are needed to provide an adequate diaphragm. Collectors to steel diagonal bracing and around the stack will require careful design consideration. The design of this diaphragm at Elevation 68 ft will be the subject of future review by the PRT.

It is expected that after the design team incorporates the omega factor in its collector/drag strut calculations, the adequacy of the steel studs and transfer of forces from the structural steel beams of the diagonally braced bays into the concrete slabs the overall concrete and steel design will be shown to meet code requirements. Confirmation of this will be the subject of a future review by the PRT.

The PRT believes the load path is adequately understood allowing this abbreviated summary structural report to be published.

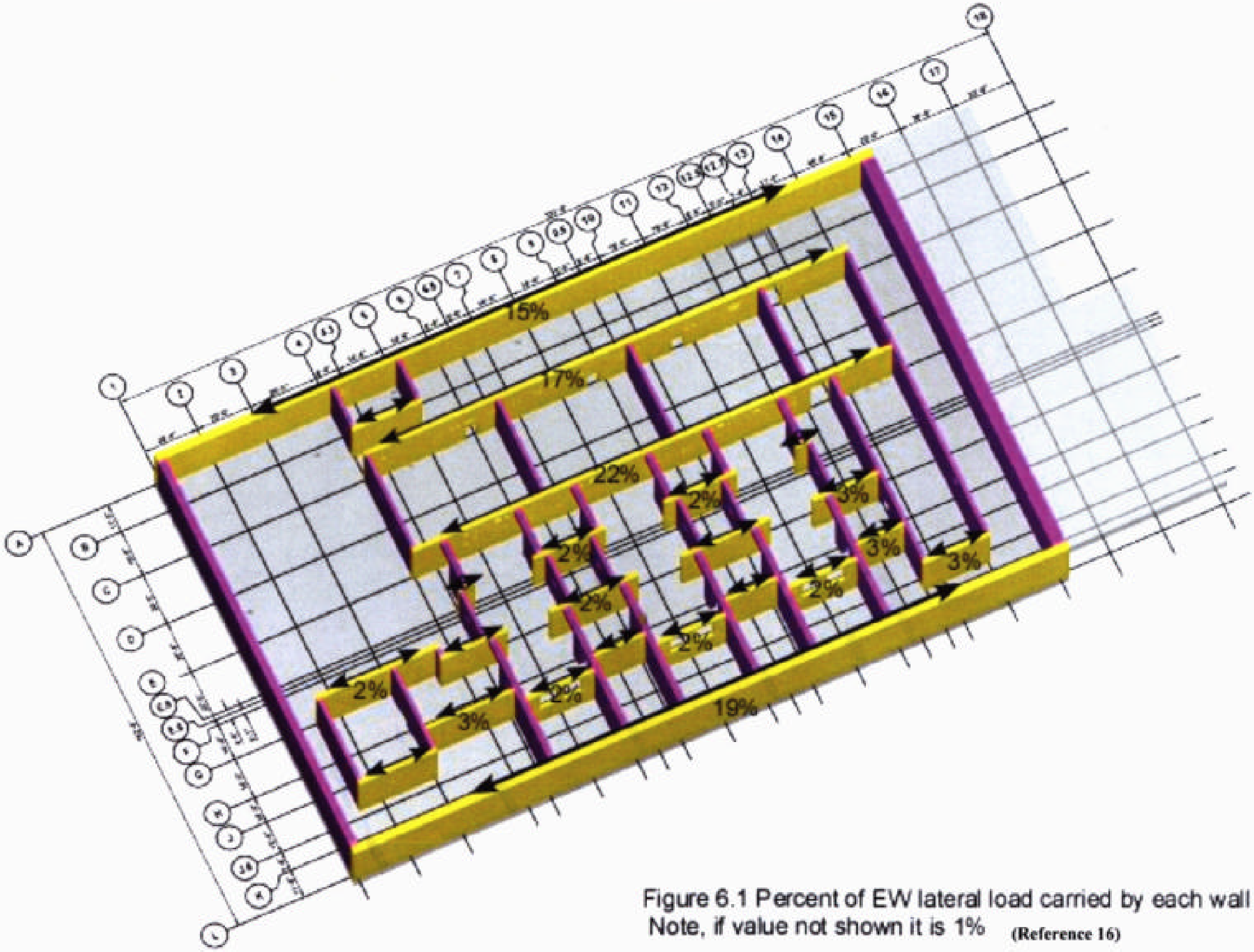


Figure 6.1 Percent of EW lateral load carried by each wall
Note, if value not shown it is 1% **(Reference 16)**

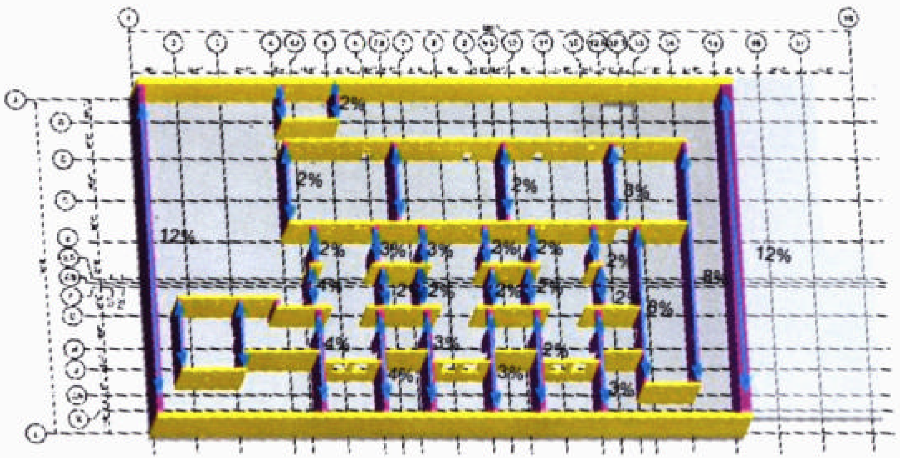


Figure 6.2 Percentage of Story Shear taken by Walls
Note; Values not shown are 1% **(Reference 16)**

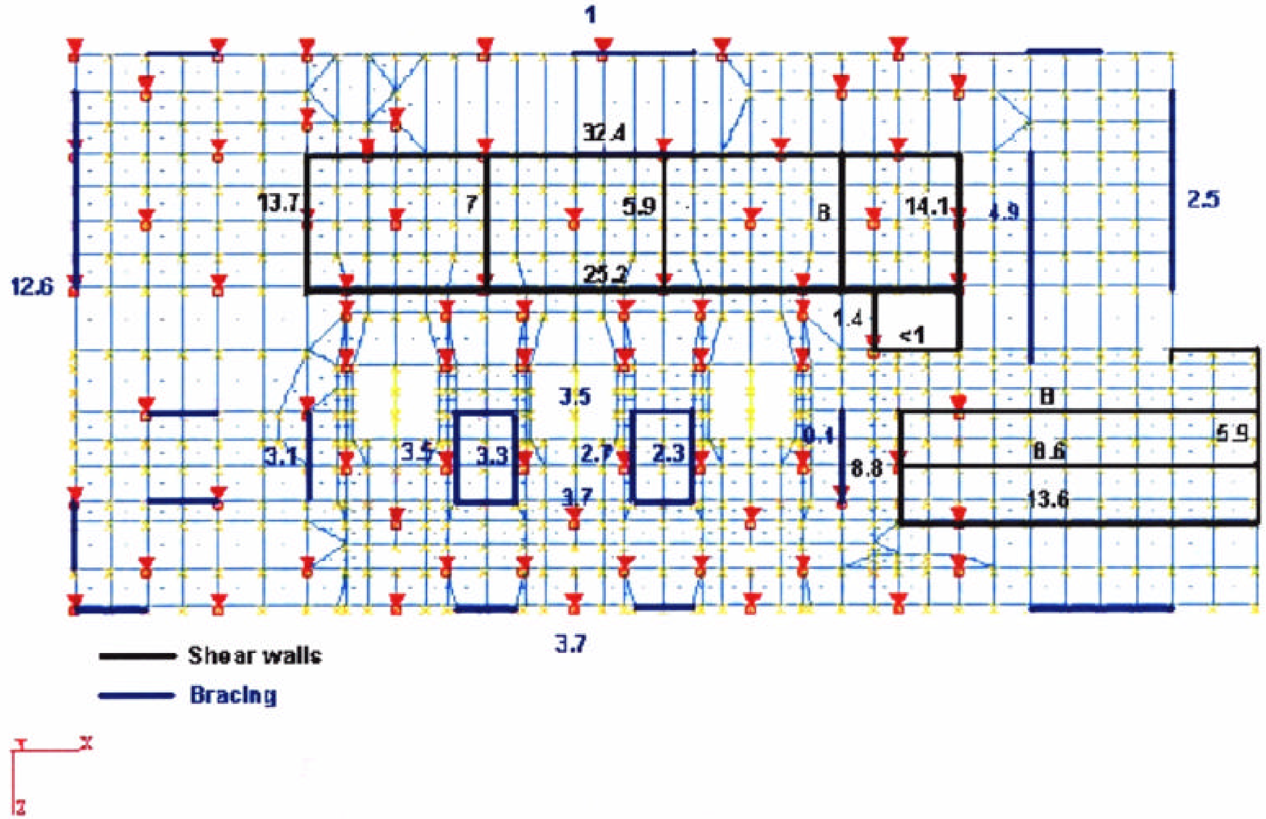
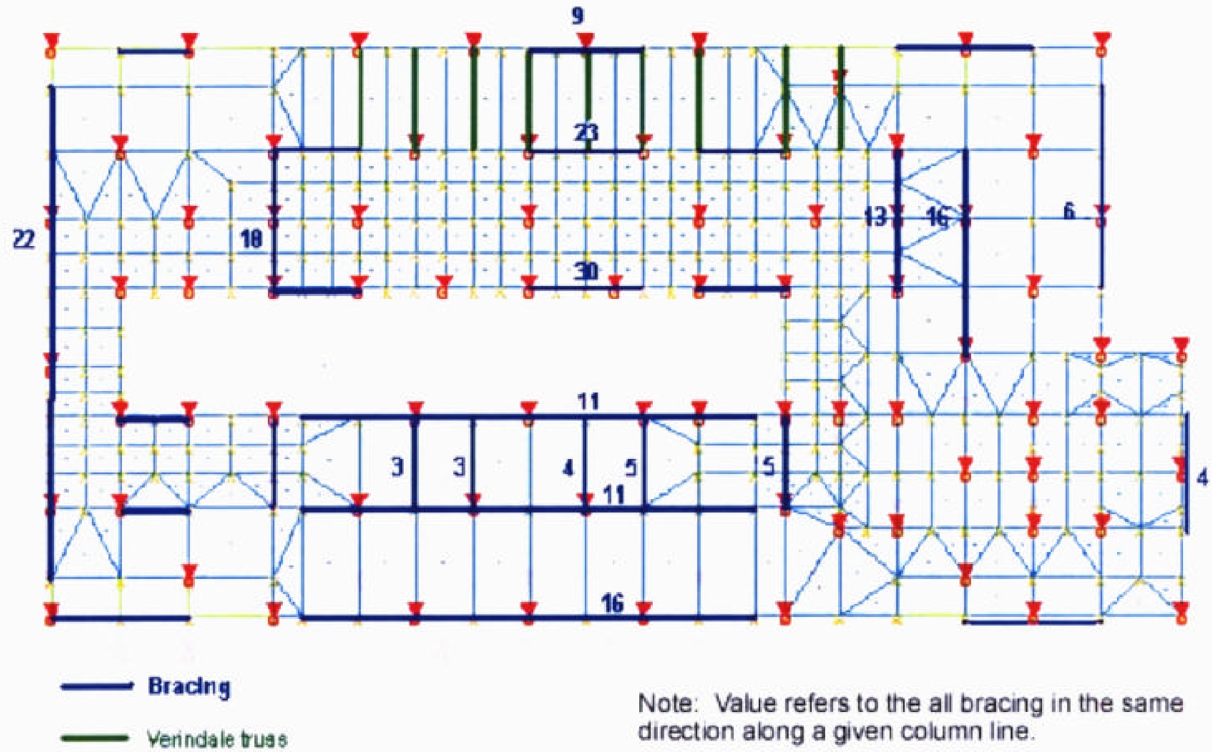


Figure 6.3 Percentage of Lateral Load in Walls and Braces, Elevation 3 ft (Reference 16)



Note: Value refers to the all bracing in the same direction along a given column line.

Figure 6.4 Percentage of Lateral Load Carried by Elevation 28 to 48 ft Braces and Trusses (Reference 16)

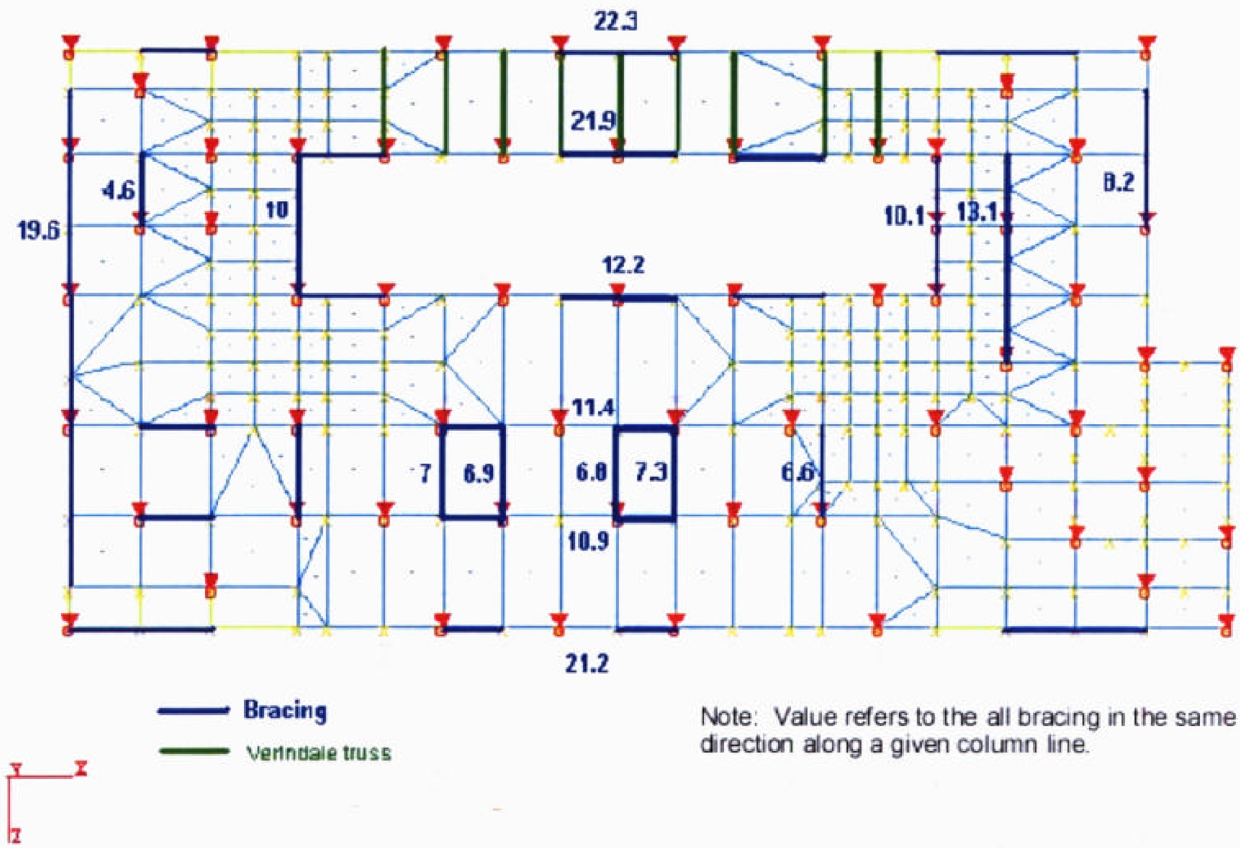


Figure 6.5 Percentage of Lateral Load Carried by Elevation 48 to 68 ft Braces and Trusses (Reference 16)

7 Structural Analyses

Structural analyses determine structural demands for all loading conditions and applicable load combinations. BNI is using a mix of hand calculations and computer analyses to determine the structural demands for the LAW building.

Typically, hand calculations are used to develop structural demands for:

- basement walls with out-of-plane loading,
- elevated floor slabs with out-of-plane loading,
- simple span steel floor beams,
- adding auxiliary loads to columns, and
- miscellaneous support steel.

Typically, computer analyses are being used to develop structural demands for:

- shear walls,
- steel bracing,
- in-plane membrane forces in slabs,
- both in-plane and out-of-plane forces in the soil supported basemat, and
- axial loads in steel floor beams.

Generally, the PRT agrees that this mix of hand and computer analyses is appropriate for the determination of the LAW structural demand. The remainder of this chapter presents results and conclusion of the PRT reviews of the specific analysis calculations.

7.1 Hand Calculations

7.1.1 Exterior Below Grade Walls

Exterior below grade walls are assumed to cantilever from the basemat during construction and resist active lateral soil pressure in addition to construction surcharge loadings (compactor). Once the Elevation +3 ft floor slab is in place, the below grade walls resist;

(1) at-rest lateral soil pressure;
(2) operating surcharge loads such as a melter or the building foundation East of Column Line 15; and
(3) lateral seismic loadings equal to the ASCE 4 elastic solution.

The walls are analyzed for out-of-plane loadings using fixed-free beam model for construction loads and fixed-pinned beam models for operating and NPH loads, as discussed in Calculation 24590-LAW-DBC-S13T-00011 Rev 2B.

In-plane shear and tension chord demands for the basement walls are determined from the computer analysis.

7.1.2 Elevated Floor Slabs

Elevation +3 ft Floor slabs span horizontally between steel floor beams and are designed as one-way slabs in Calculation 24590-LAW-DBC-S13T-00015 Rev A. Bending moments due to gravity and vertical seismic loads are determined by ACI moment coefficients (uniform loads) and beam formulas (concentrated loads). A similar approach is used for the design of the Elevation +28 ft floor slabs in Calculation 24590-LAW-DBC-S13T-00028 Rev A.

In-plane shear and tension demands for the elevated slabs are determined from the computer analysis.

Calculations 24590-LAW-DBC-S13T-00015 and -00028 contain analyses which assume that an internal fire damages some steel floor beams and the floor slab spans in an alternate directions, with a much longer spans, to fire proofed beams.. The PRT has been informed that this concept is no longer applicable and that the additional reinforcing is not installed. Consequently, the PRT has omitted the internal fire portion of the calculations from its review.

7.1.3 Structural Steel Floor Beams

Structural steel floor beams are designed as simple span members in Calculation 24590-LAW-SSC-S15T-00009 Rev 0 (Elevation +3), 24590-LAW-SSC-S15T-00032 Rev A (Elevation +28), and 24590-LAW-SSC-S15T-00049 Rev 0 (Elevation +48). Structural steel beams at floor openings between exterior below grade walls and floor diaphragms also transfer axial loads. Axial loads in beams with concrete slabs are resisted by the concrete slab.

7.1.4 Auxiliary Column Loads

Selected bays have structural steel platforms that are supported by steel columns at mid-height. The highest platform will have an elevation of 58 ft. Lateral column loads resulting from these platforms are developed, by hand calculation, in 24590-LAW-SSC-S15T-00033 Rev A and combined with the column loads from the computer analysis.

The magnitude of lateral loading in Calculation 24590-LAW-SSC-S15T-00033 is based on UBC Section 1632 and results in an effective platform acceleration that is less than the Elevation 48 ft floor acceleration – which is not defensible. The platforms are considered to be rigidly mounted equipment, with a spectral amplification term, ap=1. Realistically, the platform's lateral stiffness is dependent on its column stiffness. The natural frequency of these platforms, supported by columns, should be assumed to be on the peak of the response spectra with an amplification, ap=2.5.

It also appears that the total platform load consist of a 50 psf collateral load, which is used as a seismic mass to determine the lateral seismic load. The platform dead weight and live load (if any) could not be identified in the calculation.

The PRT recommends that BNI (1) ensure that all dead and live platform loads are considered; and (2) increase the lateral seismic load on columns due to platforms.

7.2 Computer Analyses

A three dimensional (3D) GTStrudl model of the LAW building is utilized to evaluate the building for gravity, NPH and accident loads. The results of this analysis are the demands for shear walls, columns, steel bracing, the basemat and slabs (membrane forces). The computer analysis is also used to determine the building drift.

7.2.1 Computer Model

The LAW computer model is shown in Figures 7.1 and 7.2. The LAW structural analysis is performed with the GTStrudl computer code, Version 25.

7.2.1.1 Model Versions

The computer model used to determine demands in the LAW has evolved as the geometry and member sizes changed and the loadings were refined. The PRT is aware of 9 different computer models representing the LAW, which are summarized in Table 7.1. The scope of the updates is summarized in Table 7.2. Additional models, not listed in Table 7.1, are appended to specific design calculations. For example, Calculation 24590-LAW-DBC-S13T-00009 contains additional computer models with moving melter loads.

Revision of structural demands due to model changes and load refinement is a part of every project. One important component of this process, which was not observed by the PRT, consists of constantly assessing the impact of analysis updates on previously designed, and possibly constructed, components. Failure to continually perform these assessments could result in expensive modifications. The PRT recommends that BNI assess, and document, the impact of analysis updates on previously designed components.

Table 7.1 LAW Structural Analyses

Update	Date	File	Calc # 24590-LAW-SOC-S15T-	Description
S0	2/7/02	Jan23.gts	00001	Represents geometry as of 1/23/02
S1	4/15/02	Mar20.gts	00009	Incorporates geometry changes between 1/23/02 and 3/20/02.
S2	7/11/02	April18a.gst	00010	Incorporates geometry changes between 3/20/02 and 4/18/02.
S3	10/15/03	Aug15-03.gts	00013	Incorporates geometry changes between 4/18/02 and 8/15/03.
S4	11/06/03	Sept24-03.gts	00014	Incorporates geometry changes between 8/15/03 and 9/24/03.

Thermal Update	Date	File	Calc # 24590-LAW-DBC-S13T-	Description
T0	7/11/02	May22.gts	00016	Thermal analysis for basemat, pour cave and buffer storage Based on Update S2
T1	10/15/03	Sept803.gts	00026	Thermal analysis for finishing line Based on Update S3
T2	11/06/03	Oct6-03.gts	00027	Thermal analysis for finishing line Based on Update S4
Taccident	3/27/02	See CCN #030846	00014	Basemat glass spill accident thermal analysis Based on Update S0

Table 7.2 Summary of LAW Analyses Updates

Summary of Changes in Update 1 1. Remove elements at Elevation +3 floor openings 2. Modify floor beam sizes 3. Refine mesh and remove elements at Elevation +28 and +48 floor openings 4. Adjust bracing location and member sizes to manage column reactions
Summary of Changes in Update 2 1. Raised the wall on Column Line 4 2. Added a door to the wall on Column Line 4 3. Changed floor slab between G12.7 and J14 from 3' thick non-composite to 18" thick composite
Summary of Changes in Update 3 1. Removed a significant conservativism in the seismic base shear 2. Removed F_t from the vertical load distribution 3. Reduced the amplification for torsional and vertical irregularities 4. Changed the finishing line walls at column lines 16, 17 and 18 which required numerous adjustments on the east end of the model 5. Added openings on G and J.3 6. Added a Vierendeel truss on column line 5
Summary of Changes in Update 4 1. Changed the size of diagonal bracing members on column lines 1, 2, 4, 6, 7, 9, 10, 12.5, 14, 15, 17, 18, A, C, E, G, J and L 2. Added two columns on column line G between elevation +28 and +48

7.2.1.2 Model Geometry

A comparison of the Update S3 computer model with design drawings indicates that the computer modes provide a reasonable replication of the design.

Concrete basemats, walls and slabs are represented in the model by 3091, four-noded plate elements. The plate elements have a fairly coarse mesh with average element sizes of 8 to 10 ft wide, which is typical in all updates. In the PRT's opinion, the mesh refinement is sufficient to distribute lateral loads to different shear walls and braced bays.

A total of 2156 beam elements are used to represent steel columns, bracing and primary girders. The stiffness of secondary floor framing, purlins, girts and miscellaneous steel members are omitted from the model.

The Update S3 model has 3183 nodes of which 684 are part of the basemat. All 684 basemat nodes in the LAW building model have both vertical and horizontal soil springs. The soil springs represent the subgrade modulus acting over a tributary nodal area.

Vertical and horizontal subgrade moduli, observed in the Update S3 GT Strudl model, are summarized below. Note that softer subgrade moduli are assumed for the fill area under the surface basemat at Elevation +3 ft.

Mat Elevation	Vertical Subgrade Modulus		Horizontal Subgrade Modulus	
(TOC)	Static	Dynamic	Static	Dynamic
+3	70 kcf	70-140 kcf	List the values84% Kvertical	List the values57% Kvertical
-21	175 kcf	350 kcf		

7.2.1.3 Loading

Loads are identified in many calculations as unverified assumptions that should be updated as vendor information becomes available.

The free field spectra used to calculate the UBC '97 base shear is shown in Figure 7.3. In the long period, or constant velocity, portion of the spectra, acceleration is Cv/T, where Cv is 0.32g-sec and T is the natural period of the structure. In the short period, or constant acceleration, portion of the spectra, the acceleration is 2.5Ca, where Ca=0.24g. From the original analysis, up to and including Update 2, the LAW seismic loading was determined by extrapolating the equation for the constant velocity portion of the spectra into the constant acceleration region. Beginning in Update 3 the correct portion of the spectra was used to determine seismic loads.

The elastic response acceleration in Figure 7.3 is modified by I/R, where I is the importance factor, I=1.25, and R is the response modification factor for a shear wall building, R=4.5. For LAW, the design base shear, V, is:

$$V = 2.5\ Ca\ I\ W/R = 0.166\ W,$$

where W is the seismic weight (D+25%L) of the building.

The design base shear of 0.166W is observed in Calculation # 24590-LAW-SOC-S15T-00013.

It appears that the weight of the basemats at Elevation -21 and +3 are included in the seismic weight of the building. Including the basemat mass in the UBC base shear equation is conservative because it requires that the walls above the basemat to be capable of resisting the seismic forces from the mat. In reality, these forces are transferred directly from the mat to the ground and are not transferred through the walls. Note that the basemat weight at the -21ft elevation is roughly 32,500 kips which, is about 25% of the total seismic weight, W=128,420 kips, used to calculate base shear. Thus, the design base shear applied to the LAW building may have a significant conservativism.

7.2.1.4 Seismic Analysis Methodology

Calculation 24590-LAW-S0C-S15T-00001, Rev 0 acknowledges that the LAW building has a vertical geometric irregularity according to UBC Table 16-L and a horizontal diaphragm discontinuity according to UBC Table 16-M. Following the guidance of UBC Section 1629.8, the dynamic lateral force procedure of Section 1631 would have been used for the LAW building. Instead, the LAW seismic analysis methodology consist of a modified static lateral force procedure, which uses a dynamic analysis to determine the vertical distribution of shear forces. Overall, the PRT believes that the LAW analysis methodology will yield appropriate lateral forces.

In more detail, the seismic analysis methodology for LAW consists of:

- Design base shear is calculated in accordance with UBC Section 1630.2.1.
- The vertical distribution of forces is determined from a modal response spectra analysis.
- Static nodal forces are generated at each node, which are the product of the modal response spectra acceleration and nodal mass.
- The static nodal forces are scaled such that the base shear is equal to the design base shear.
- Horizontal torsional moments are calculated using UBC Section 1630.7, which amplifies the 5% accidental torsion to account for torsional irregularities.
- Horizontal torsional moments are introduced in the model by shifting scaled static nodal forces horizontally on each floor. North, South, East and West shifted force cases are considered.
- Seismic demands are determined via a static analysis.

This process is illustrated in Table 7.3 where elastic modal forces are summed on each story and reported as Elastic Modal Story Force. Note that the elastic modal results do not include the effects of I/R. These forces are contrasted to the UBC Vertical Distribution of forces calculated using Equation 30-15. The Elastic Modal Story Forces are scaled to match the UBC Design Base Shear and reported as Factored Story Forces. These Forces are divided by the story mass to yield an Average Story Acceleration. The Story Amplification Factor includes the 5% accidental torsion and the amplification for torsional irregularities. The Final Story Acceleration is the product of the Average Story Acceleration and Story Amplification Factor.

Table 7.3 Seismic Forces in Update #3 [24590-LAW-S0C-S15T-00013 Rev A]

Elevation (ft)	Elastic Modal Story Force (k)	UBC Vertical Distribution (k)	Factored Story Force (k)	Average Story Acceleration (g)	Story Ampl. Factor	Final Story Acceleration (g)
68&Stk	7036	2771	4469	0.958	1.2	1.149
48	8931	6331	5673	0.416	1.15	0.478
28	5651	5287	3589	0.227	1.1	0.249
3	5616	6056	3567	0.101	1.05	0.106
-21	6464	958	4105	0.069	1.05	0.073
Total	**33698**	**21403**	**21403**			

Note that the same acceleration is used for both the stack and the Elevation 68 ft roof in Table 7.3. This practice severely underestimates the acceleration in the stack as shown by Calculation # 24590-LAW-SOC-S15T-00013, which reports 3.25g acceleration at the top of the stack from the modal analysis. This acceleration is more than twice the average modal analysis roof acceleration of about 1.5g's. The PRT recommends that an appropriate stack acceleration, which is significantly larger than the Elevation 68 roof acceleration, be used to determine demands on the stack and its supporting structure.

Cumulative shear is derived from Table 7.3 by summing the UBC Vertical Distribution and the Factored Story Force and is shown in Figure 7.4. Note that at elevations 28 ft and 3 ft the cumulative shear due to the factored modal story force is less than the UBC vertical distribution. The PRT recommends that BNI justify the use of the cumulative shear distribution d in their design.

Notes On Modal Response Spectra Analysis

Attachment C of Calculation 24590-LAW-S0C-S15T-00013 Rev A (Update #3) reports a modal analysis base shear of 33,698 kips, which is based on a dead load of 123,678 kips and does not include the UBC I or R factors. Assuming that the response spectra in Figure 7.3 was used, then the modal analysis base shear should be scaled by I/R and the modal base shear is only V = 33,698 I/R = 0.076 W. Comparing the modal base shear to the UBC '97 base shear (0.166W) shows that the modal base shear is roughly one-half of the UBC base shear. This is probably because a significant portion of the LAW mass participates at very short periods (i.e. the basemat at -21 is rigid, T=0) and represents a significant source of conservativism in the LAW seismic design.

The PRT recommends that BNI reexamine the modal analysis and quantify the difference between the modal base shear and the UBC base shear. This information is important to understanding the true seismic margins inherent in this structure.

7.2.2 Structural Behavior

Lateral drifts of the building, based on the Update 4 analysis, are summarized in Table 7.4. As expected for a shear wall/braced frame building, these lateral drifts are relatively small and are well below the UBC allowable drift. Note that the portion of the building with reinforced concrete shear walls, below Elevation 28, is much stiffer than the upper steel superstructure.

The PRT was not able to locate lateral drifts for the steel stack but displaced geometry plots in Calculation 24590-LAW-S0C-S15T-00013 suggest that the stack displacement is several times larger than the displacement at Elevation 68. The PRT recommends that the stack displacement be considered in the design of the stack supported ducts and equipment to ensure the stack safety function is met.

Table 7.4 LAW Lateral Drifts (Displacements)

	Calculated [24590-LAW-SSC-S15T-00033]		UBC '97 Allowable	
Story	Δ	Δ/H	Δ	Δ/H
48' to 68'	3.31 in	$1/72$	6 in	$1/40 = 0.025$
28' to 48'	1.79 in	$1/134$	6 in	
+3' to 28'	0.91 in	$1/330$	7.5 in	

The lateral natural frequencies of the LAW building, calculated in Calculation 24590-LAW-S0C-S15T-00013, are 2.9 Hz in the east-west direction and 2.6 Hz in the north-south direction. These natural frequencies probably represent the response of the braced frame above elevation 28 ft and it is expected that the fairly rigid shear wall portion of the structure below elevation 28 ft would have significantly higher natural frequencies. This is supported by noting that the steel superstructure above Elevation 28 in Table 7.4 is considerably more flexible than the reinforced concrete shear wall portion of the structure. [Are there any mode shapes in the calculation that can be shown?]

7.3 Integration of Analysis and Design

Table 7.5 summarizes the structural analyses used to design various structural elements. Note that as the design progresses from the basemat to the roof, the analyses are refined and the analytical results more accurately reflect the final geometry and applied load distribution. This allows conservative assumptions to be relaxed compared to earlier analyses updates.. Thus, a reported 0.7 demand-to-capacity ratio in the basemat probably overestimates the demand-to-capacity ratio if loads from a later analysis update were used.

The LAW design process primarily consist of hand calculations, which include computer generated analysis results as input. The use of computer output ranges from; (A) conservatively assuming that the peak hot-spot in-plane shear stress on a wall is acting uniformly over the entire wall; to (B) taking section cuts which accurately reflect the total in-plane shear stress. Both methods are acceptable but method A is inherently more conservative than method B; and demand-to-capacity ratios generated by the two different methods are not directly comparable.

As discussed previously, a coarse mesh with elements 8 to 10 ft' wide is used to determine LAW building stresses. Coarse meshes often underestimate the peak stress at a discontinuity. Thus, designing a component for the peak stress from a coarse mesh will not be as conservative as designing the same component for the peak stress of a fine mesh. The PRT has not observed any uses of peak stress, developed from a coarse mesh, that are unconservative.

The steel floor beams carry axial loads in the computer model. The design assumes that these beams transfer axial loads to the concrete slabs and omits axial loads from the simple beam connections to supporting columns and walls. The PRT was not able to locate calculations transferring the ultimate strength beam loads (ie. concrete load combinations) into the concrete and demonstrating that the concrete is capable of resisting those loads.

The PRT recommends that BNI ensure that the ultimate strength beam loads are transferred into the concrete slab and these loads are resisted in the concrete slab.

Table 7.5 Use of Structural Analyses in Design Calculations

Design Component	Concrete Calc 24590-LAW-DBC-S13T-	Steel Calc 24590-LAW-SSC-S15T-	Analysis Update(s)
-21 Basemat	00009		S0, T00, Taccident
+3 floor slab	00015		T0
+3 Steel Framing		00009	S2
+28 floor slab	00028		S4
+28 Steel Framing, Non-Process Cell		00032	S4
+48 floor slab	TBD		TBD
+48 Steel Framing		00049	S4
Basement walls	00011		S1, T0
Upper Process Cell Walls	00023		S2
Finishing line walls	00022		T1
Steel Columns		00016	S1
Steel Column Design +3 to +68		00033	S4
Steel Bracing		00021	S1
Bracing above +3		00027	S4
Steel Welded Moment Connection		00029	S2

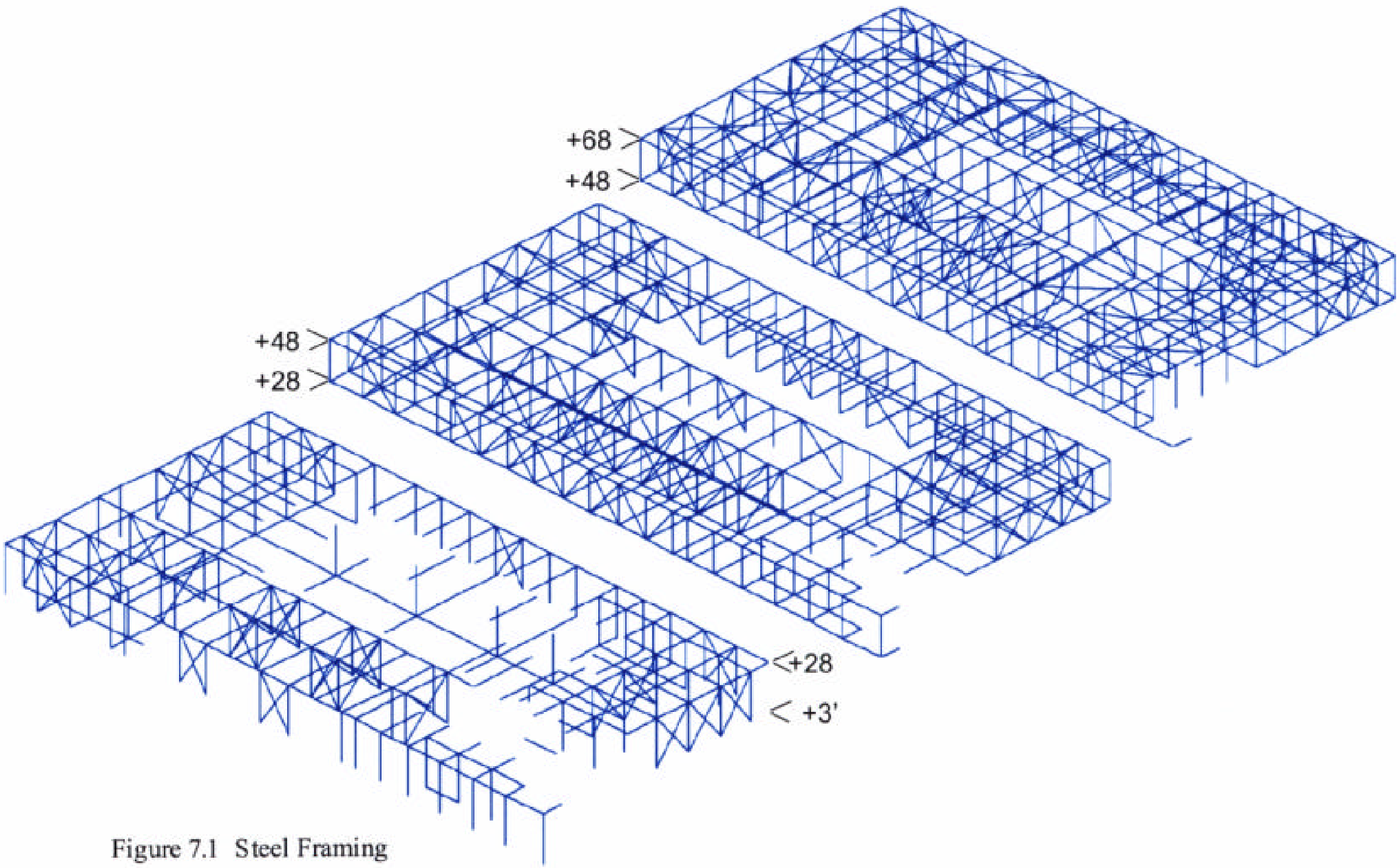


Figure 7.1 Steel Framing

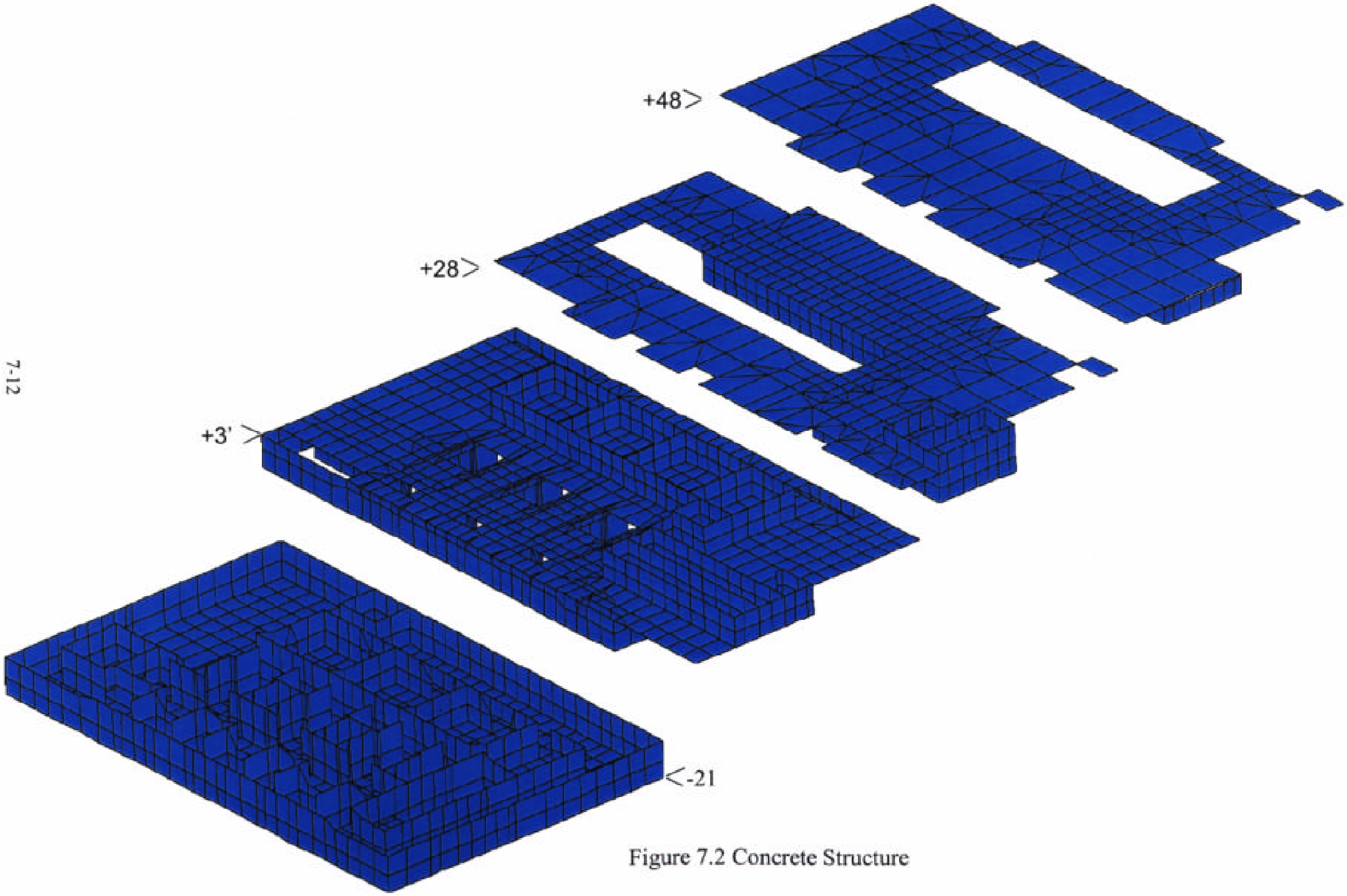


Figure 7.2 Concrete Structure

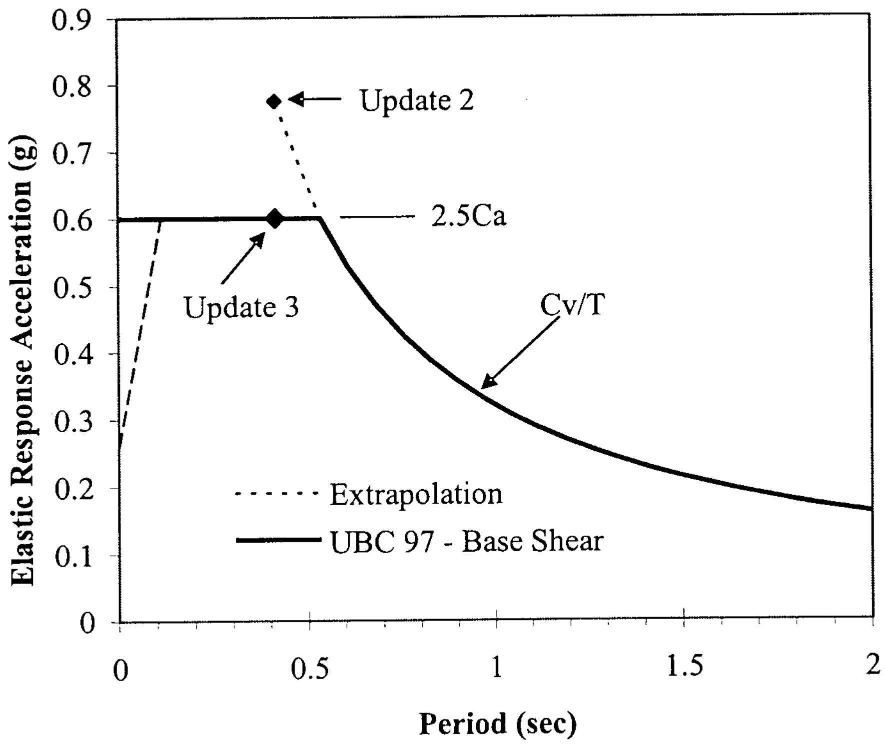


Figure 7.3 UBC '97 Base Shear Spectra

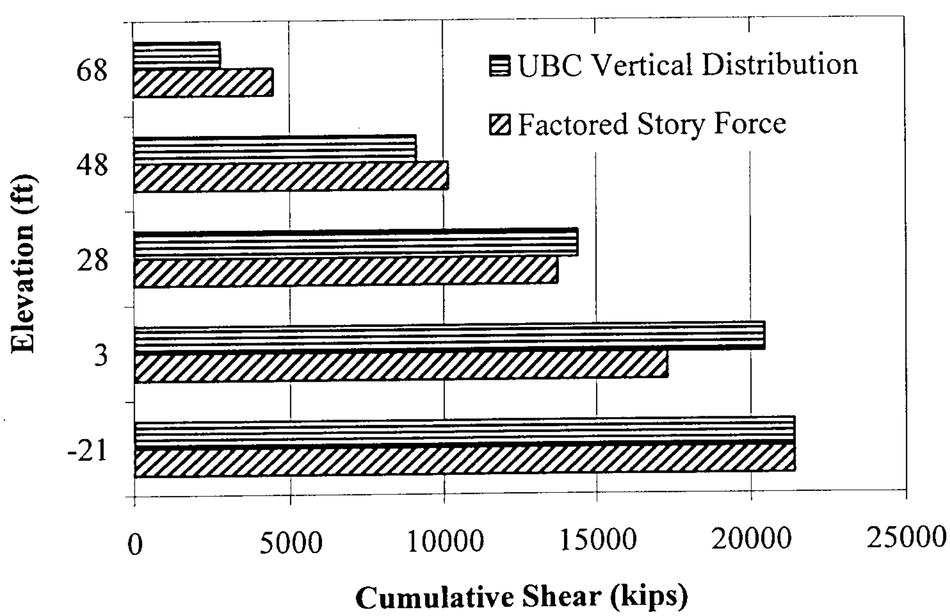


Figure 7.4 Cumulative Story Shears

8 Design Results

A successful design must provide both adequate member capacities and structural detailing. Ductility is used to significantly reduce the seismic demands in the LAW building by a factor of 4.5. Structural detailing is essential to ensure that this structure has sufficient ductility to accommodate the seismic force reduction without collapse. Capacities are required to resist these reduced demands.

8.1 Structural Capacities

8.1.1 Reinforced Concrete

The PRT observed that reinforced concrete was designed in accordance to the ACI 318-99 code. Generally, the capacities are in compliance with the code requirements with the following exception.

The out-of-plane shear capacity in the basemat, Calculation 24590-LAW-DBC-S13T-00009 Rev 2, is based on an ACI shear strength reduction factor of $\phi = 0.9$ (Sheet C1-L, C1-M). ACI 318-99 Section 9.3.2 requires $\phi = 0.85$ for shear. The PRT recommends that BNI reevaluate out-of-plane shear in the basemat using the a strength reduction factor, ϕ =0.85.

8.1.2 Structural Steel

The PRT observed that structural steel members are designed in accordance with the AISC ASD, 9th Edition.

8.1.3 Cast-In-Place Concrete Embedments

The PRT observed that cast-in-place embedment plate anchorage, shear lugs and anchor bolts are designed in accordance with ACI 349-01.

8.1.4 Post Installed Concrete Anchorage

The PRT did not observe any calculations concerning post-installed concrete anchorage. However, the following specifications for ITS and Non-ITS applications were observed:

- 24590-WTP-3PS-FA02-T00005 Rev 0, Design of Post Installed Concrete Anchors for Important to Safety (ITS) Applications.
- 24590-WTP-3PS-FA02-T00003 Rev 0, Design of Post Installed Concrete Anchors for Non-Important to Safety (Non-ITS) Applications.

It is believed that these specifications will provide adequate anchorage.

8.2 Structural Detailing

The PRT has reviewed the structural drawings which have been released for construction, paying particular attention to the structural details. In general, the PRT has found the most structural details to be in accordance with normal accepted practice. However, there are some details that the PRT believes do not meet this criterion. The following sections deal with those specific areas where the PRT has taken issue with the BNI design.

8.2.1 Structural Steel Diagonal Bracing Connections

The connections of concern are the typical beam to column connections where diagonal braces frame into this connection both above and below the beam. Three separate details must be reviewed to see and understand the entire connection. The beam is connected by a shear tab welded to the column and bolted to the beam. The diagonal braces are a pair of structural tees which are bolted to a gusset plate. The gusset plate above the beam is connected to both the beam and column with bolts to steel angles bolted to both the gusset plate and beam or column. The gusset plate below the beam is similarly connected except that the gusset plate is welded to the column. The PRT believes this detail was requested by construction to provide a pre-welded bearing seat to facilitate steel erection. All of the bolts are high strength bolts which were designed as bearing bolts.

During the PRT's initial review of the LAW Building in January 2004, an objection was raised to this detail. The objection was that the connections to the column include a welded gusset below the beam and high strength bolts designed to act in bearing at the beam and above the beam. This is in obvious violation of the Uniform Building Code and the American Institute of Steel Construction's Specification which forms the basis of the structural steel code within the US. The code specifically disallows welds and bolts in bearing from sharing load, as the bolts in bearing theoretically have to slip into bearing to reach their capacity, whereas, the weld will not slip, making load sharing impossible. BNI has argued that they consulted the AISC Steel Solutions Center which agreed with their design. The PRT strongly disagrees with this guidance and judges that the connection does not comply with the code. The code describes "faying surfaces" and the PRT is of very strong opinion that entire connection of beam and both gussets to column constitute one "faying" surface where welds and bearing bolts cannot share loads.

BNI responded to the PRT in a draft memorandum dated June 3, 2004, which was discussed in concept during the PRT visit to Richland, WA. They provided calculations with the A490 bolts at the face of the column reconsidered as "slip critical" or tension bolts designed to a lower capacity prior to slip. The PRT accepted this philosophy to the design of this connection, but after an in depth review of the June 3, 2004, and reviewing the calculations in Attachment 2 to that draft letter, the PRT has the following additional comments:

1. The capacity of the beam to column connection is given as 467.7 kips reflecting the capacity of the shear plate welded to the column. The PRT disagrees. The capacity of the beam to column connection cannot be taken greater than the capacity of the ten 1-1/8 inch diameter bolts as SC, or slip critical, bolts, reducing the beam to column connection capacity to 209 kips.

2. The weld of the horizontal 11 x 3/4 inch plate below the beam is given as 245 kips of capacity resisting the vertical shear transfer to the column. No calculation has been provided demonstrating the strength or stiffness of this horizontal plate in weak-way bending to transfer these vertical shear forces to the column. The PRT does not believe that this full weld capacity can be used to resist the vertical shear force, as the plate will bend and may yield in weak-way bending before the full weld capacity can be achieved in vertical shear.

3. To summarize, by reducing the capacity of the beam connection and the horizontal plate, the capacity is very close to the demand. The PRT requests that the BNI design team refine their calculations of this connection to demonstrate adequate capacity and margin. The PRT believes this connection was not properly conceived in design and BNI has yet to demonstrate its adequacy. This issue remains an open item.

8.2.2 Moment Resistant Frames North of Line C

As a result of the long opening over the Process Cells at the Elevation +48 ft slab and the observation in preliminary design that this long, skinny piece of diaphragm displaced excessively under seismic loads, a series of moment resistant frames or Vierendeel Trusses have been designed between column lines A and C from Elevations +28 ft to Elevation +68 ft. The PRT believes this was a very good design decision to stiffen this portion of the diaphragm. Vierendeel Trusses or Moment Resisting Frames are provided on lines 5, 6, 7, 8, 9, 10, 11, 12.5 and 13 from elevation +28 ft to +68 ft with horizontal beams at +38.5 ft, +48 ft and +58.5ft. The beams at +38.5 ft and +58.5ft are unbraced for their full length of 29 feet from lines A to C.

Following the PRT meeting of June 1 to 3, 2004, BNI provided a copy of their calculation for the beams at Elevation +38.5 (24590-LAW-SSC-S15T-00054). The beams were designed for the laterally unbraced length of 29 feet which significantly reduces their capacity in comparison to a braced beam. The PRT recognizes that even though this system of Vierendeel Trusses is somewhat a secondary system it does significantly reduce the diaphragm deflections at Elevation +48 ft. The PRT is concerned that the weak link of these Vierendeel Trusses is at +38.5 ft and +58.5 ft and is buckling or lateral instability of these 29 foot long laterally unbraced beams.. Since there are significant pipe runs and other utilities in these high bay areas from A to C at the Elevation +28 ft and Elevation +48 ft floors, the PRT suggested that BNI add east-west beams at +38.5 ft and +58.5 ft at the approximate third points of the 29 foot span and to add horizontal steel diagonal bracing members to form a horizontal steel braced diaphragm with struts to laterally brace the beams of the Vierendeel Trusses at one or two bays in plan.

The PRT requests that BNI seriously consider this suggestion to prevent non-ductile behavior of the LAW Building. DOE 1020 requires the building to be detailed for ductile performance during an earthquake and this design modification would be towards achieving that goal. Premature buckling or lateral instability of beams in seismic overloads would result in ductile performance. The PRT believes that some intermediate beams for pipe and commodity support may be needed at these levels so the cost and effort of this addition for enhanced performance should be minimal.

9. Structural Margins in Analysis and Design

Demand-to-capacity ratios (D/C) are used to indicate the structural margins, or the ability of a structure to support its design loads. Demands for the LAW building are discussed in Chapter 7 and capacities are discussed in Chapter 8.

In general, the PRT believes the demands and capacities for the LAW building are conservatively calculated. However, the PRT has questioned specific demands and capacities in several structural components in the body of this report. This chapter summarizes BNI's structural margins, the conservatism inherent in the LAW design and balances the conservatism against the issues raised throughout the report.

9.1 Structural Margins

Structural margins for the LAW, extracted from the BNI calculations, are summarized in Table 9.1. Where applicable, the margins have been scaled to reflect the true margins by removing the management reserve factors of either (0.85C) or (1.15D).

Several calculations do not contain demand to capacity summaries. Some, particularly the floor steel calculations, demonstrated that the required section modulus was less than the actual section modulus and did not provide demand to capacity ratios. While both methods result in adequate building design, the section modulus comparison makes it burdensome to summarize the structural margins. The PRT observed Elevation 3 ft steel floor framing demand-to-capacity ratios as high as 0.98 by comparing required and supplied section moduli in the body of calculation 24590-LAW-S15T-00009. The PRT did not attempt to compare all of the section moduli in the 618 page calculation for the Elevation 28 ft steel framing, 24590-LAW-SSC-S15T-00032.

As discussed previously, the PRT does not agree with the calculation of structural demand in Elevation 3 ft and Elevation 28 ft collector elements (omega factor, Ω). The demand-to-capacity ratios shown in Table 9.1 are still under review.

Note that the maximum axial stress observed in a column is roughly 40% of the allowable axial stress. The high column demand-to-capacity ratio, D/C = 0.999 is due to the combination of peak axial loads, bending moments, crane loads, etc. for a group of columns.

Generally, the D/C ratios in Table 9.1 are close to unity, which, by itself, suggests the LAW building does not have significant reserve capacity. Conservativisms in the structural margin are discussed in the following section.

Table 9.1 Reported LAW Demand to Capacity Ratios

Design Component	D/C	Loading	Analysis (Table 7.1)
Elevation -21 ft Basemat	0.84	Seismic Bending	S0, T00, Taccident
Elevation 3 ft Floor Slab	0.66 0.94 0.88*	Normal Operations Seismic In-Plane Shear Seismic Collector Element	T0
Elevation 3 ft Steel Framing	0.98**	Normal Operation	S2
Elevation 28 ft Floor Slab	0.48 0.88 0.82*	Normal Operations Seismic In-Plane Shear Seismic Collector Element	S4
Elevation 28 ft Steel Framing, Non-Process Cell	***		S4
Exterior Basement Walls	0.85	Seismic In-Plane Shear	S1, T0
Upper Process Cell Walls	0.89	Seismic out-of-plane bending	S2
Finishing line walls	0.97	Thermal + Seismic	T1
Steel Columns below Elevation 3 ft	0.86	Seismic axial+ bending	S1
Steel Column Design +3 ft to +68 ft	0.999	Seismic axial+ bending	S4
Steel Bracing below Elevation 3 ft	0.48	Seismic axial compression	S1
Bracing above Elevation 3 ft	0.85	Seismic axial compression	S4

Notes: Actual D/Cs are shown – D/C have been scaled to remove management reserve of (0.85C) or (1.15).

* The PRT does not concur with this value.

** D/C not calculated, highest observed ratio of required to provided section modulus in the body of the calculation.

*** D/C not calculated.

9.2 Conservatism in Structural Margins

9.2.1 Conservative Management Controls

The PRT observed that management controls were used to increase the margin by 15% in the following calculations:

- In Calculation 24590-LAW-DBC-S13T-00009, the entire basemat at Elevation -21 ft has an additional 15% margin.
- In Calculation 24590-LAW-DBC-S13T-00009, the basement walls below Elevation 3 ft have an additional 15% margin. The dowels between the basement wall and the Elevation 3 ft slab do not include the additional 15% margin.

The margin was obtained in the calculations by either increasing the demand by an additional 15% (1.15D) or reducing the capacity by 15% (0.85C).

9.2.2 Conservative Load Application

The PRT believes that the gravity loading used in the LAW design is generally conservative. Specific examples of conservative load application are:

- An 80 psf commodity loading is used on the elevated floor slabs for piping, raceway and ductwork. This commodity load is used to develop both gravity and lateral seismic loading.
- A 20 psf partition load was uniformly applied to each floor. The partition load is used to develop both gravity and lateral seismic loading.
- The weight of major equipment is generally believed to be conservative.

The PRT endorses the LAW design team's generally robust application of gravity loads. These loads are appropriate given the degree of uncertainty in the LAW processes equipment when the design was initiated.

9.2.3 Conservative Analysis and Design Procedures

The LAW building analysis and design process contains several unquantified conservatisms that enhance the structural integrity of the building. Some of these that were apparent to the PRT include the following:

- The seismic design base shear in the original analysis, Update 1 and Update 2 is 29% larger than required by UBC. This conservativism was removed in the Update 3 analysis. The building below Elevation 3 ft and the process cell walls were designed with seismic loads that are 29% larger than required by UBC. This conservativism may have been removed in a portion of the Elevation 3 ft floor slab in response to collector element questions.

- It appears that the weights of the basemats are included in the seismic weight of the building, which is used to calculate the UBC Design Base Shear. It is estimated that removing the weight of the Elevation -21 ft basemat alone would result in roughly a 25% reduction in base shear.

- Nodal accelerations from the modal analysis, which form the basis of the seismic loads at individual nodes, include the torsional response from its structural irregularities. Torsional loads due to irregularities are added a second time during the equivalent static lateral load procedure. At the roof this translates to roughly a 15% increase in the acceleration. This conservativism does not exist at Elevation 3 ft and lower.

- The modal analysis, modified by I/R, appears to have a seismic base shear that is roughly one-half of the UBC Design Base Shear. This includes seismic loads from basemat mass and double counting the torsional response as discussed above; along with conservativism in the UBC static load procedure.

- Some components are designed using the peak stress from stress contour plots when section cut force could have been used. The peak stresses are usually significantly larger than section cut forces, which average the contour stresses over a specified length.

- Some components, such as columns, are designed for the enveloping forces from different elements and different load combinations. The actual forces for a single load combination acting on any column are smaller.

9.3 Unconservatism in Structural Margins

Unconservatism noted previously in this report are summarized below:

- The PRT observed that an incorrect strength reduction factor, ϕ, had been used for the basemat out-of-plane shear capacity. This will increase basemat shear demand-to-capacity ratios by the ratio 0.9/0.85, or about 6%.

- The PRT believes that the demand in the seismic demand in collector elements is unconservative. BNI is currently determining if alternate load paths are capable of resisting these loads.

- The PRT believes that the acceleration in the stack is too low and underestimates the axial load on columns under the stack. The magnitude of this unconservatism is unknown. At worst, this could require the strengthening of steel columns under the stack and bracing around the stack.

- The PRT believes that the lateral load applied to columns from platform loads is unconservative for platforms that are high in the building. This may be offset by the reduced column load at higher elevations. At worst, this issue could require local strengthening of steel columns.

The PRT has made specific recommendations for each of these unconservative areas.

10 Conclusions and Open Issues

The LAW structure is designated as Seismic Category III (SC-III) for earthquakes and performance category 2 (PC-2) for other natural phenomena hazards. The design is in accordance with the 1997 Edition of the Uniform Building Code with a seismic Importance Factor, I, of 1.25. The project is "close-coupled" meaning the design is completed in phases with construction of each phase following closely.

A Structural Peer Review has been performed for the Low Activity Waste (LAW) Facility of the Waste Treatment and Immobilization Plant (WTP) at the Hanford DOE Site. The peer review has taken place during the January to June 2004 time period. The design is currently about 75% complete while construction is about 30% complete.

The PRT has found, in general, that the design has been competently prepared and in accordance with the criteria and applicable codes. The PRT has reviewed construction drawings and selected portions of many calculation packages attempting to review those items which the PRT believes to be critical issues for a fully successful structural design of the building. Conclusions for each major report section plus open issues, if any, are summarized below.

10.1 LAW Structural Design Criteria

The review of LAW structural design criteria and resulting loads in Chapter 5, concluded that the design loads used in the LAW design generally contain an adequate level of conservatism as long as the assumed equipment loads are validated when vendor information becomes available. The PRT has recommended the following changes to Structural Design Criteria 24590-WTP-DC-ST-001 be made so it is current with the ongoing design process:

- **LAW-18, Structural Criteria Update**. The Structural Design Criteria 24590-WTP-DC-ST-001 needs to be updated to reflect current LAW design approach.
- The load combinations should include the special load combinations of UBC-97 Section 1612.4, which amplify the load in certain elements (i.e. collectors) by the factor omega, Ω.
- The anchorage criteria should be updated to include recent post installed anchor criteria in 24590-WTP-3PS-FA02-T00005 Rev 0, *Design of Post Installed Concrete Anchors for Important to Safety (ITS) Applications*, and 24590-WTP-3PS-FA02-T00003 Rev 0, *Design of Post Installed Concrete Anchors for Non-Important to Safety (Non-ITS) Applications*.
- The PRT recommends that BNI develop II over I evaluation criteria for structures, systems and components and include this criteria in the Structural Design Criteria.

10.2 LAW Seismic Load Path

The seismic load path was evaluated in Chapter 6 and concluded that load path is adequately understood by designers and an abbreviated summary structural report could be published. However, there are several issues related to load path and structural detailing that must be addressed. The report restates several open items previously transmitted to BNI plus the following new load path issues.

LAW-19, Load Path Issue at Elevation +3 Slab. The major load transfer issues at Elevation 3 ft involves transferring seismic loads out of the north-south walls above Elevation 3 ft on lines 4, 6.5, 9.5, 12.5 and 14 from lines C to E to the extensive north-south walls south of line E below Elevation 3 ft. There appears to be a considerable gravity load north-south compression in the 3 ft floor slab in the vicinity of line E which reduces the seismic tension calculated by the project's load combinations.

Although not verified, it is believed to be a result of the very heavy weights of the melters on the Elevation 3 ft slab just south of line E. Since this gravity compression may not be a reliable permanent load considering construction sequence and melter installation, the PRT recommends that these gravity load compressions not be used to reduce seismic collector loads.

LAW-20, Utilization of Stress Plots. The design approach has been to utilize the color coded stress contour plots which plot shear or tension in the concrete slab to guide the designers to locate section cuts and calculate reinforcing steel. The PRT has the following observations and possible concerns regarding the adequacy of this procedure.

The PRT is not certain that the design procedure has adequately captured all the collector demands at Elevation 28 ft. The calculations reviewed did not include the omega factor, which may increase the reinforcing required and will alter the process the design team uses to review the color coded tension plots. The PRT recommends that the design team review its procedures and performs additional section cuts in areas of moderate tension to ensure that all collector demands are adequately reinforced.

The PRT is concerned that the present design procedure of using the color coded concrete tension plots may not envelope high tension forces in the steel framing members. The PRT could not locate any steel tension contour plots or determine how high steel beam tension forces were identified for design. The PRT recognizes that large numbers of similar beams were bracketed for common design. BNI should identify how they address this issue to ensure that high tension forces in steel beams are properly addressed in design process, including the use of omega for collector loads. While this issue applies to Elevation 28 ft, it will also apply at higher levels in the building.

10.3 LAW Structural Analysis

BNI is using a mix of hand and computer analyses to determine the structural demands for the LAW building. Generally, the PRT agrees that this mix of hand and computer analyses is appropriate for the determination of the LAW structural demand. Several questions resulted from detailed review of BNI calculations which need to be addressed by the LAW team.

LAW-21, Updates on Previously Designed Components. BNI should assess and document, the impact of new analyses updates on previously designed components. The PRT did not identify this assessment in the calculations they reviewed.

LAW-22, Stack Acceleration. The PRT believes that the stack will have larger accelerations than the Elevation 68 ft roof acceleration currently used in the analyses. BNI should calculate a stack acceleration and it should be used to determine demands on the stack and its supporting structure, including columns and bracing below Elevation 68 ft.

LAW-23, Base Shear. BNI should reexamine the modal analysis and quantify the difference between the modal base shear and the UBC base shear. This information is important to understanding the true seismic margins inherent in this structure.

LAW-24, Platform Loading. BNI should:

1. Ensure that all dead and live loads acting platforms are considered; and

2. Increase the lateral load acting on columns, due to platform weight, to reflect the column flexibility, (ie use the UBC factor, ap=2.5).

LAW-25, Cumulative Story Shear. Justify why a cumulative story shear at Elevations 3 ft and 28 ft, which is less than the UBC cumulative story shear from Equation 30-15, is acceptable.

LAW-26, Stack Supported Utilities. The stack displacement should be considered in the design of stack supported ducts and equipment to ensure the stack safety function is met.

LAW-27, Transfer of Beam Loads. BNI should ensure that the ultimate strength beam loads, as developed in the analysis model, are transferred into the concrete slabs and that these loads are resisted in the concrete slabs.

10.4 LAW Design Results

The PRT identified the following new issues on both structural capacity and detailing in Chapter 8.

LAW-28, Basemat Out-of-Plane Shear. The PRT recommends that BNI reevaluate out-of-plane shear in the basemat, Calculation 24590-LAW-DBC-S13T-00009 Rev 2, considering the correct strength reduction factor, ϕ .

LAW-29, Vierendeel Truss Bracing. The PRT recommends that BNI provide lateral bracing the Vierendeel Trusses beams at Elevations +38.5 ft and +58.5 ft.

LAW-30, Bracing Connections. The PRT recommends that the BNI design team refine their structural steel bracing connections calculations to demonstrate adequate capacity and margin. Specifically, (1) the full 245 kips of capacity of the horizontal 11 x 3/4 inch plate in vertical shear is not defensible; and (2) the capacity of the beam to column connection cannot be taken greater than the capacity of the ten 1-1/8 inch diameter bolts as SC, or slip critical, bolts.

10.5 LAW Structural Margins

Chapter 9 evaluates demand to capacity ratios at key locations within the LAW structure and concludes that in many instances, the ratios are close to 1.0. The PRT believes that in many instances the design loadings, analysis and design procedures are conservative. Loadings, analysis and design procedures that the PRT considers unconservative have been identified as open issues and will be resolved.

10.6 Previous Open Issues

Three design reviews have occurred prior to and during preparation of this report. Although not entirely discussed in this report, the following open issues that have been provided to the design team under separate cover are included here for reference.

LAW-7, Load Transfer from Braced Frames. BNI needs to provide adequate detailing of seismic load transfers into and out of steel braced frames at various slab elevations.

LAW-11, Amplification of Collector/Drag Strut Forces. During the PRT review of 6/3/04, it was noted that BNI had not used the appropriate over strength factor for collector steel. BNI needs to evaluate all slabs above 3+ to assure code is met and evaluate slab at 3+ to assure brittle failure does not occur.

LAW-14, EW tension steel vicinity line 12 South of line H. The E-W steel at elevation 28 between column lines H to J should be rechecked to assure adequacy.

LAW-15. Bracing of compression flanges in Moment Resistant Frames. Calculations for bending in the girders of the Vierendeel truss could not be identified. The degree of bending in truss girders could not be found in the calculation. In addition, calculations should verify that unbraced compression flange lengths of some the truss chord members are adequate.

LAW-16, Slab Reinforcement at Elevation 28'. In light of LAW 11, the PRT believes that a careful re-review of the design of the reinforcement in the slab at elevation 28' be conducted considering amplified seismic collector and drag strut forces. Many of the blue areas on the tension plots, when amplified, may need heavier than typical slab reinforcing to transfer seismic forces.

LAW-17, Tension in steel beams. A brief review of structural steel calculations indicates considerable tension in many of the steel floor beams. BNI should identify how they address this issue considering many beams were bracketed for common design.

The PRT will verify closure of all open items as well as continue in their periodic review of LAW and other WTP facilities.

A. References

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

2 Project Document No. WTSC99-1036-42-17, Shannon & Wilson, Inc., RPP-WTP Geotechnical Investigation Final Report, May 2000 including April 2001 Supplement.

3 Geomatrix Consultants. Probabilistic Seismic Hazard Analysis, DOE Hanford Site Washington, WHC-SD-W236_TI-002, Revision 1a, prepared for Westinghouse Hanford Company, Richland, Washington, October 1996.

4 Natural Phenomena Hazards Design and Evaluation for Department of Energy Facilities, DOE-STD-1020-94 including Change Notice #1 dated January 1996

5 Seismic Analysis and Design Approach (SADA), Document No. 24590-RPT-ST-01-002, 8/15/2001

6 24590-WTP-DC-ST-01-001, Rev 1, *Structural Design Criteria*

7 Code Requirements for Nuclear Safety Related Concrete Structures (ACI 349-01)

8 Building Code Requirements for Structural Concrete (ACI 318-99)

9 Manual of Steel Construction, Allowable Stress Design, AISC, Ninth Edition, 1989. (AISC)

10 GT STRUDL, Release 25, A Bechtel Standard Computer Program, by Georgia Tech Research Corporation, Atlanta Georgia, Integrated CAE System for Structural Engineering Analysis and Design

11 International Conference of Building Officials, 1997 Uniform Building Code, (97 UBC)

12 ASCE 7-98, Minimum Design Loads for Building and Other Structures

13 Steel Deck Institute Design Manual for Composite Decks, Form Decks and Roof Decks No. 30 Institute, April 2001

14 International Council of Building Officials Evaluation Services (ICBO-ES) Reports

15 Lateral Load Path in the Low Activity Waste Vitrification Building, 24590-LAW-RPT-CSA-02-002, Rev A (draft)

Calculations Reviewed

1. 24590-WTP-3PS-FA02-T00003 Rev 0, *Design of Post Installed Concrete Anchors for Non-Important to Safety (Non-ITS) Applications.*
2. 24590-WTP-3PS-FA02-T00005 Rev 0, Design of Post Installed Concrete Anchors for Important to Safety (ITS) Applications
3. 24590-LAW-S0C-S15T-00001, *GTStrudl Finite Element Analysis Model*
4. 24590-LAW-S0C-S15T-00002 Rev 2, *LAW Floor Loading*
5. 24590-LAW-S0C-S15T-00005 Rev 1, *Wind Loads on the Building*
6. 24590-LAW-S0C-S15T-00007, Rev 0, *Loading Conditions*
7. 24590-LAW-S0C-S15T-00010, *GTStrudl FEA Model Update 2*
8. 24590-LAW-S0C-S15T-00013 Rev A, *GTStrudl FEA Model Update 3*
9. 24590-LAW-S0C-S15T-00014, *GTStrudl FEA Model Update 4*
10. 24590-LAW-SSC-S15T-00009 Rev A, *Steel Framing (EL +3')*
11. 24590-LAW-SSC-S15T-00015 Rev A, *Bogie Maintenance Monorail*
12. 24590-LAW-SSC-S15T-00016, *Building Steel Column Design*
13. 24590-LAW-SSC-S15T-00021, *Building Steel Bracing Design*
14. 24590-LAW-SSC-S15T-00023 Rev A, *Process Cell Steel Framing*
15. 24590-LAW-SSC-S15T-00027, *Bracing Member Design Above +3 Elevation*
16. 24590-LAW-SSC-S15T-00029, *Steel Welded Moment Connection Design*
17. 24590-LAW-SSC-S15T-00032, Rev A, *Steel Framing, Non-Process Cell @ 28'*
18. 24590-LAW-SSC-S15T-00033, *Steel Column Design +3 to +68'*
19. 24590-LAW-SSC-S15T-00049, Rev 0, *Steel Framing @ 48'*
20. 24590-LAW-SSC-S15T-00054, *Steel Beams @ 38.5'*

21. 24590-LAW-DBC-S13T-00001 Rev 1, *Foundation Wall Calculation for Lateral Soil Loads*

22. 24590-LAW-DBC-S13T-00005 Rev 0, *Thermal Analysis for the Basemat and Pour Cave Walls*

23. 24590-LAW-DBC-S13T-00009 Rev 2, *Foundation Basemat Design*

24. 24590-LAW-DBC-S13T-00011, Rev 2B, *Basemat Wall Design*

25. 24590-LAW-DBC-S13T-00014, *Basemat Analysis For Glass Spill*

26. 24590-LAW-DBC-S13T-00015 Rev A, *Elevated Floor Slab Design @ +3'*

27. 24590-LAW-DBC-S13T-00016, *Thermal Analysis for Basemat, Pourcave, & Buffer Storage Area*

28. 24590-LAW-DBC-S13T-00018, *C3/C5 Area Exterior Wall Analysis*

29. 24590-LAW-DBC-S13T-00022, *Finishing Line Shear Wall Design*

30. 24590-LAW-DBC-S13T-00023, *Upper Process Cell Shear Wall Design*

31. 24590-LAW-DBC-S13T-00026, *Thermal Analysis Update 1 for Finishing Line*

32. 24590-LAW-DBC-S13T-00027, *Thermal Analysis Update 2*

33. 24590-LAW-DBC-S13T-00028, Rev A, Elevated Floor Slab Design @ 28'

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